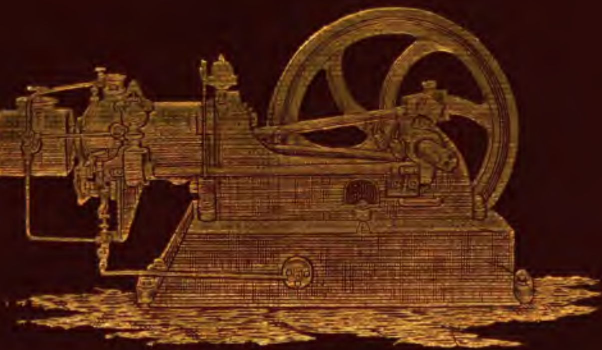
·OIL · ENGINES·



GOLDINGHAM

THE

DESIGN AND CONSTRUCTION

OF

OIL ENGINES

ERRATA.

Foot Note: on page *22*, second line should read;
$=2$ c.— 0.01 c^2. (c. &c. **not**, $= 2$ c. — 0.01 c. (c.&c.
Foot Note: on page 221, should read No. 5, not p. 5.
Foot Note: Should go on page 236;
To convert calories per lb. to B.T.U's per lb. multiply by 1.8
To convert calories per lb. to calories per kilogram multiply by .45 35 92.

NEW YORK:
SPON & CHAMBERLAIN, 123 LIBERTY ST.

LONDON:
E. & F. N. SPON, LTD., 125 STRAND

1904

THE

DESIGN AND CONSTRUCTION

OF

OIL ENGINES

ERRATA.

Foot Note: on page 22, second line should read;
$= 2\,c. - 0.01\,c^2$. (c. &c. not, $= 2\,c. - 0.01\,c$. (c.&c.
Foot Note: on page 221, should read No. 5, not p. 5.
Foot Note: Should go on page 236;
To convert calories per lb. to B.T.U's per lb. multiply by 1.8
To convert calories per lb. to calories per kilogram multiply by .45 35 92.

NEW YORK:
SPON & CHAMBERLAIN, 123 LIBERTY ST.
LONDON:
E. & F. N. SPON, LTD., 125 STRAND
1904

THE

DESIGN AND CONSTRUCTION

OF

OIL ENGINES

WITH FULL DIRECTIONS FOR

ERECTING, TESTING, INSTALLING RUNNING AND REPAIRING

INCLUDING DESCRIPTIONS OF AMERICAN AND ENGLISH

KEROSENE OIL ENGINES

By A. H. GOLDINGHAM, M.E.

Fully Illustrated

SECOND EDITION, REVISED AND ENLARGED

NEW YORK:
SPON & CHAMBERLAIN, 123 LIBERTY ST.
LONDON:
E. & F. N. SPON, LTD., 125 STRAND
1904

THE BURR PRINTING HOUSE, FRANKFORT AND JACOB STS.,
NEW YORK, U. S. A.

PREFACE TO SECOND EDITION

THE first edition having been exhausted, and in order to meet the continued and increasing demand for this work, a new and larger edition is now presented.

It has been the endeavor of the writer to embody in the present edition the most recent information on the subject. Chapters on "Oil Engine Troubles," "Fuels" with numerous tables, and "Miscellaneous," including fire insurance rules, have been added, while large-sized oil engines and portable engines have received a more extended description.

Reference to all types of engines has been made about which information could be secured.

The writer is indebted to Professor William Robinson for permission to reproduce tables from "Gas and Petroleum Engines;" also to Messrs. Clifford Richardson and E. C. Wallace for the matter given regarding Texas crude oil; to the "Scientific American" for Fig. 92*a*.

PREFACE

THIS work has been written with the intention of supplying practical information regarding the kerosene or oil engine, and in response to frequent requests received by the writer to recommend such a book.

Whilst many works have been published on the subject of gas engines, some of which refer to or describe the working of the oil engine, no other book, it is believed, is devoted entirely to the oil engine in detail.

The work, it is hoped, will be found useful to the draughtsman, the engine attendant, as well as to those who own or are about to install Oil Engines.

The classification of vaporizers has been adhered to as made some few years ago, and a representative engine with each type is described.

The matter on design and construction is founded on practical experience, the formulæ, it is believed, being in accordance with the best modern practice.

Chapter III. on Testing is based on the writer's personal experience in the testing-room.

The writer is particularly indebted to Mr. George Richmond for many valuable suggestions, and also for reading the proof-sheets, and he wishes to acknowledge assistance from many firms, amongst which may be mentioned Ingersoll Sargeant Drill Company for Table III., Mr. Frank Richards for Table II., The De La Vergne Company for Table IV., *London Engineer,* Tables V. and VI. Table I. is partly taken from Mr. William Norris's book on the Gas Engine, and Tables VII., VIII., IX., and X., at the end of the book, relating to different oils, are taken (with permission) from Mr. Boverton Redwood's valuable work on Petroleum. And to the *Engineering News* for permission to use Figs. 44*b* and 44*c*. The Crosby Steam Gauge Company have also supplied information relating to the indicator and planimeter.

A. H. GOLDINGHAM.

NEW YORK, November 1, 1900.

CONTENTS.

CHAPTER I.

INTRODUCTORY.

CHAPTER II.

ON DESIGNING OIL ENGINES.

CHAPTER III.

TESTING ENGINES.

CHAPTER IV.

COOLING WATER-TANKS AND OTHER DETAILS.

CHAPTER V.

OIL ENGINES DRIVING DYNAMOS.

CHAPTER VI.

OIL ENGINES CONNECTED TO AIR-COMPRESSORS, WATER-PUMPS, ETC.

CHAPTER VII.

INSTRUCTIONS FOR RUNNING OIL ENGINES.

CHAPTER VIII.

REPAIRS.

CHAPTER IX.

OIL ENGINE TROUBLES.

CHAPTER X.

VARIOUS ENGINES DESCRIBED.

CHAPTER XI.

PORTABLE ENGINES.

CHAPTER XII.

LARGE SIZED ENGINES.

CHAPTER XIII.

FUELS.

CHAPTER XIV.

MISCELLANEOUS.

TABLES

LIST OF ILLUSTRATIONS

CHAPTER I.

INTRODUCTORY.

THE internal combustion engines which are treated of in this work are those using heavy kerosene as fuel, otherwise called petroleum, coal oil or Scotch paraffin, and similar oils having specific gravity varying from .78 to .85 with flashing point of 75° to 300° Fahr.

The use of heavy oil for producing power in internal combustion engines appears to have received the attention of inventors as early as 1790, though no satisfactory practical kerosene or petroleum engine is recorded as having been made until about thirty years ago. Those engines using the lighter grade fuels, such as benzine, or gasoline, or naphtha, were commonly used previous to the invention of the kerosene-oil engine. The problem of efficiently producing a vapor and suitable explosive mixture of air with such vapor from these light oils was comparatively a very simple matter. Such engines are gas engines proper, with simply some form of carburetter added, but they can use only gasoline or naphtha as fuel. These are not treated of in this book, only oil engines proper being

described and discussed. The term oil engine refers to an internal combustion engine so designed as to effectively deal with and convert into power crude petroleum just as it is pumped from the earth, or any of the other fuels already named, without the aid of any outside agency or separate apparatus.

The production of a satisfactory device for properly vaporizing the heavier oils at first offered a problem which it was thought difficult to solve, and remained so for many years before the efficient vaporizing kerosene engines now in use were constructed.

IGNITERS.—The first oil engines built had their charge of vaporized oil and air ignited by means of the flame igniter, which has, however, now entirely given place to the four following means of ignition:

(*a*) Hot surface ignition, aided by compression.

(*b*) Hot tube.

(*c*) Electric igniter.

(*d*) High compression only.

The first-named type of igniter is illustrated in Fig. 1. In this instance the heated walls of the vaporizer act as the igniter, aided by the heat generated during compression of the gases. The chamber being first heated, afterward the proper temperature is maintained by the heat caused by the internal combustion of the gases. The best-known vaporizer and igniter of this type is that in the Hornsby-Akroyd Oil Engine. Various other somewhat similar devices in which sufficient heat is maintained to cause ignition automatically are also now being made.

The second type, that of the hot tube, is shown in

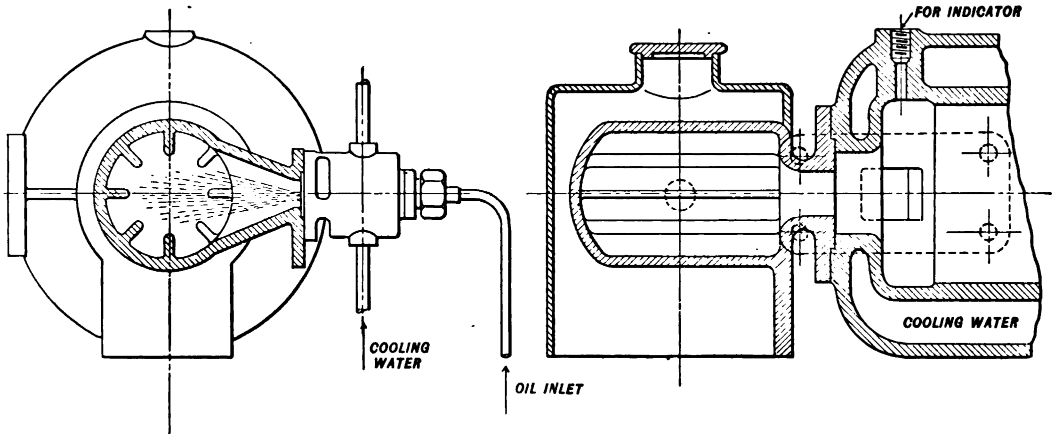


FIG. 1.

(To face p. 2.)

Figs. 2 and 3. This igniter consists simply of a porcelain or metal tube fitted into the vaporizer or cylinder wall. It is closed at one end, the other end being open to the cylinder. It is heated by a lamp, as shown in Figs. 2 and 3, over part of its length. When compression due to the inward stroke of the piston takes place in the cylinder the explosive mixture is compressed into the tube and is ignited by coming in contact with the heated portion of it. Porcelain or nickel-steel tubes are preferable to wrought iron, all of which substances are used for this purpose.

The electric igniter, which is at present more largely used for gas and gasoline engines than for oil engines, is shown in Fig. 4. Those illustrated are known as the "jump-spark" and the make-and-break types.

The jump-spark (Fig. 4) is preferred for high speeds, as it has no moving parts inside the cylinder. With this type the igniter plug containing the terminals is screwed into the cylinder cover. The method of making electrical connections is shown in principle at Fig. 4. Connection is made from the battery through the primary circuit of the Rhumkorff or spark coil to the completely insulated spring which is operated by the cam. The other connection passes from the battery to the other spring operated by the cam-shaft or other moving part of the engine. The electrodes or terminals of the plug are connected to the secondary circuit. In operation where a vibrator is used in connection with the spark coil the cam at the proper time of sparking closes the circuit, causing a series of sparks to jump across the terminals in the cylinder and ignite the gases.

The make-and-break type of igniter is shown in Fig. 4*a*. This type consists of one well-insulated stationary terminal and one terminal *H* mechanically operated. The ignition is caused by the separation of the two terminals, which produces a spark between them. Fig. 4*a* shows this igniter in connection with a magneto oscillator, which is frequently employed to furnish electrical current instead of the battery. With this apparatus the current is generated by the quick movement of the inductor, which takes the place of the armature in the ordinary dynamo, and which is caused to partly revolve by movement of the arm suitably actuated from the cam-shaft or other moving part of the engine. The magneto is a very simple device, consisting only of stationary steel magnets *K*, a cast-iron inductor which takes the place of the ordinary armature, and two coils imbedded in the frame. The action is as follows: The inductor arm *C* is raised by the roller *A* on the disc *B* attached to cam-shaft. The spring *D*, shown in Fig. 4*a*, is compressed. When the arm is released the inductor has a quick, oscillating motion, caused by spring *D*, which produces a strong electrical current. This current passes through connection *J* to insulated igniter point, and through the movable electrode *G* back to the induction apparatus. The movement of inductor lever by the heavy spring allows the collar on rod *E* to hit the arm attached to movable electrode, thus separating the two electrodes and causing a spark to pass between them.

A spark plug is shown in section at Fig. 4*b*, made by A. W. King. Advantages are claimed for this type

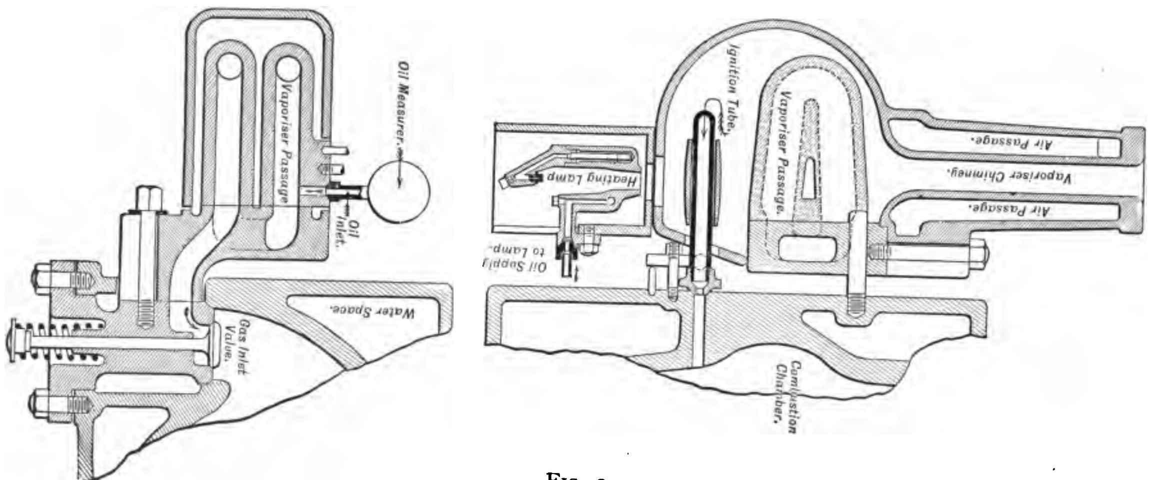


FIG. 2.

(To face p. 4.)

of plug because of the increased sparking surface of the terminal, which is formed of an inner knife-edged disc placed concentric within a thick-wall chamber, which constitutes the outer terminal. Other forms of electrical igniters are the New Standard and the Splitdorf jump-spark apparatus.

The fourth-named type of ignition, that due to compression in the cylinder alone, is found only with the Diesel motor.

Advantages are claimed for each of these igniting devices by the various manufacturers using them. The electrical igniter is easily controlled and is reliable, but the batteries in unskilled hands sometimes give trouble, and it is essential that the parts forming the contacts be kept clean and in good condition.

The tube igniter always requires heating by the external heating lamp, upon which it is dependent, like all types of vaporizers which require external heat; so likewise is also the tube dependent entirely upon it. The former difficulty with ignition tubes and their frequent bursting has now been minimized by the use of nickel alloy, porcelain or other material more suitable than wrought iron for this purpose.

The hot surface type of igniter formerly gave trouble caused by its temperature cooling down at light loads. This type, however, which has now been adopted in various forms, has been designed to overcome this difficulty, and can now be relied upon to keep hot when running at light loads.

VAPORIZERS.—As already stated, the problem of efficiently vaporizing petroleum was the most difficult feature to encounter in designing oil engines.

The present universal use of heavy oil engines is complete evidence of how any former difficulty has been thoroughly overcome, and examination of the various modern vaporizers shows extreme simplicity in operation.

The fuels used in the oil engines here discussed (crude oil, kerosene, etc.), in order to be properly vaporized, require to be broken up into the form of mist or oil vapor by spraying, or by a current of air, and then heated to a temperature above the boiling point. The oil vapor must then be thoroughly mixed with air, in order to procure complete combustion. This process is performed by various methods, as is shown in the following description of vaporizers.

The composition of various fuels is discussed in Chapter XIII.

Several oil engines having a method of vaporization are now made where the oil is injected directly into the cylinder or where it is inhaled with the air, and where both are closely regulated similar to the Priestman type of oil engine. The mixture of oil vapor and air being carried on by compression in the cylinder, ignition is caused by an electric or tube igniter. The heat from the exhaust is utilized to raise the temperature of the chamber through which the oil passes to the cylinder, which, with the heat caused by compression, is sufficient to cause vaporization and a proper mixing with the air to form an explosive mixture, the chamber, which is heated by the exhaust in operation being first heated by a lamp.

Theoretically, the amount of air required for each

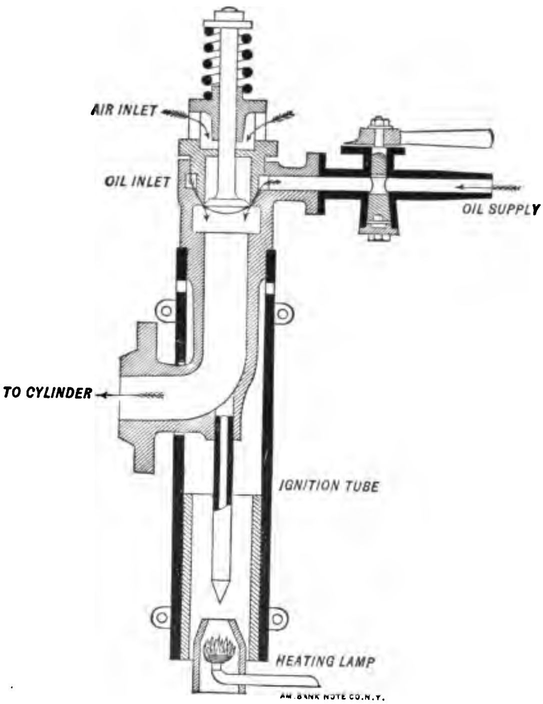


FIG. 3.

(To face p. 6.)

pound of kerosene or oil vapor is approximately 200 cubic feet at 60° Fahr. atmospheric pressure. From calculation of the amount of air taken into the cylinder, it will, however, be noted that this amount in practice is much greater. In some instances it is more than twice that amount, or 400 cubic feet. This greater volume of air is required owing to the presence in the cylinder, in operation, of a residue of the burnt products of previous explosions and to other impurities causing the efficient combustion of the oxygen of the air with the oil vapor to be somewhat retarded.

A method of starting the oil engine has of recent years been used in which alcohol, gasoline, or naphtha is burnt for a few minutes instead of kerosene. This method is advantageous in that the engine when cold can be started without the use of external heater. The lighter fuel is supplied to the vaporizer or cylinder until the vaporizing attachment has become heated by internal combustion to the temperature necessary for vaporizing the heavier fuel; then the fuel supply is changed, the supply of lighter fuel being stopped. Where an automatic igniter or vaporizer of Type 4 is used an independent electric igniter is employed to ignite the gases, and which is only in action until the vaporizer is heated.

The different types of vaporizers have been classified as follows:

1. The vaporizer into which the charge of oil is injected by a spraying nozzle being connected to cylinder through a valve.

2. That into which the oil is injected, together with some air, the larger volume of air, however, entering the cylinder through separate valve.

3. That vaporizer in which the oil and all the air supply (passing over it) is injected, but being without spraying device.

4. The type into which oil is injected directly, air being drawn into the cylinder by means of a separate valve, the explosive mixture being formed only with compression.

With each type of vaporizer some advantage is claimed, but corresponding disadvantage can perhaps be named. For instance, in type 1, though the mixture of oil and air is more complete, and the vaporizing probably greater than in the other types, yet the system of having an explosive mixture at any other place than in the cylinder and at any other period than at the time of actual ignition may be urged as a great disadvantage to this system.

With class 4 the mixture of air and oil may not be so complete, and the initial pressure in the cylinder consequent upon explosion less than the pressure obtained with other types; yet the extreme simplicity of this type is an advantage in daily use which cannot be overestimated.

With class 2 the highest mean effective pressure is obtained and the lowest consumption of oil per H. P. is believed to be recorded, but this type generally requires a heating lamp to maintain the proper temperature, and then on the efficiency of the heating lamp depends the efficiency of the engine itself. There have,

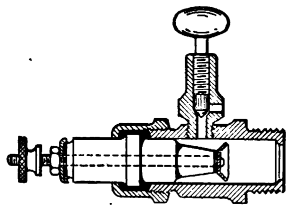


FIG. 4*b*.

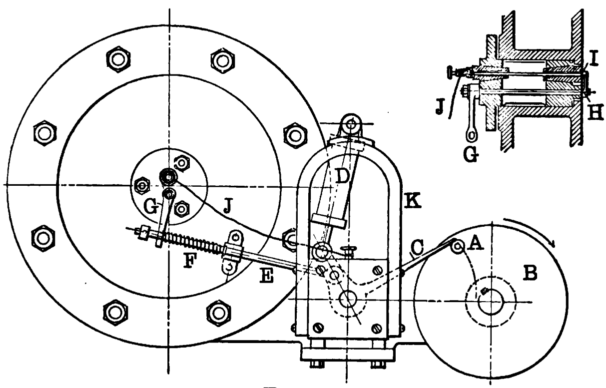


FIG. 4*a*.

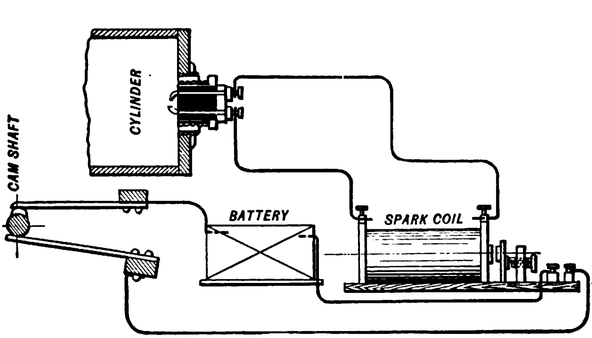


FIG. 4.

(*To face p.* 8)

in recent years, been perfected some very simple smokeless kerosene burning lamps, and this previous difficulty has now accordingly been overcome.

One of the chief difficulties in designing a satisfactory vaporizer is that of making it such that at all loads and under all conditions it will vaporize the fuel. The heat of the chamber should be high enough to vaporize the oil, but never hot enough to decompose the oil, or a deposit of carbon will be made which is injurious to the satisfactory working of the vaporizer.

It would, therefore, appear that each type, while possessing features giving it individually an advantage as compared with other types, has some detracting feature also. The following is a description of the various types of vaporizers, showing the four different methods named in detail:

THE HORNSBY-AKROYD vaporizer is shown at Fig. 1, and also as it is at present manufactured in Fig. 76, which illustrates a complete section of this engine. The oil in this method of vaporizing is injected through the spray nipple, as shown in Fig. 5, directly into the vaporizer by the oil-supply pump. The injection of oil into the vaporizer takes place only during the air-suction stroke. The lever which actuates the air-valve also simultaneously operates the oil-pump. When the piston is at the outward end of the cylinder, the suction period being then completed, the cylinder is filled with atmospheric air, and the vaporizing chamber, which is at all times open to the cylinder, is also at the same time filled with oil vapor.

The compression stroke of the piston then com-

mences; the atmospheric air in the cylinder is thus driven through the contracted opening between the cylinder and the vaporizer into the vaporizer itself, already filled with the oil vapor. The oil enters the vaporizer in the form of a thin spray or sprays and impinges on the cast-iron vaporizer wall on the opposite side, and then forms a vapor which afterwards mixes with air. Two forms of oil injectors are shown in the accompanying illustration, Fig. 5*a* being that used in connection with the later type of Hornsby-Akroyd vaporizer, which is partly water-jacketed; in this type a circular passage is made through the water-jacketed part of the vaporizer, into which the oil-spray sleeve is fitted. The water circulating around the vaporizer maintains the whole at a low temperature. Fig. 5 shows the older type of oil inlet sleeve and sprayer. Another form of oil injector made by the English makers of this engine is shown at Fig. 95. In this type the water jacket is eliminated, the heat being carried away by the surrounding air and by the fuel passing through it as it is pumped to the vaporizer. The steel spray nozzle in this type is a loose piece, being held in place by the pressure of the studs holding the sleeve containing the valve against the vaporizer. After the oil is injected into the vaporizer the compression stroke commences as this proceeds; the mixture, which at first is too rich to explode in the vaporizer, gradually becomes more diluted with the air, and when the compression stroke is completed the mixture of oil, vapor and air attains proper explosive proportions. The mixture is then ignited simply by the hot walls of this

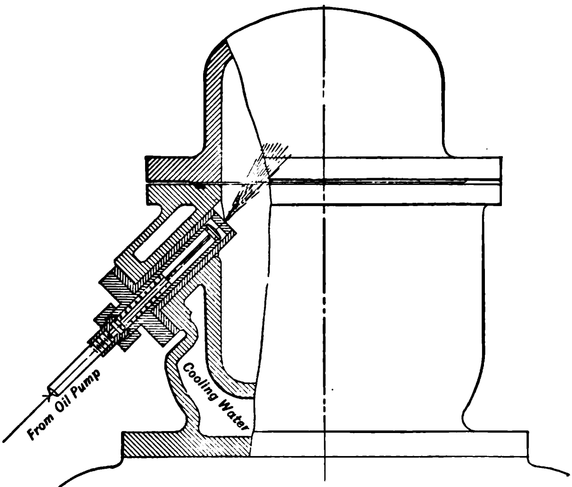


FIG. 5*a*.

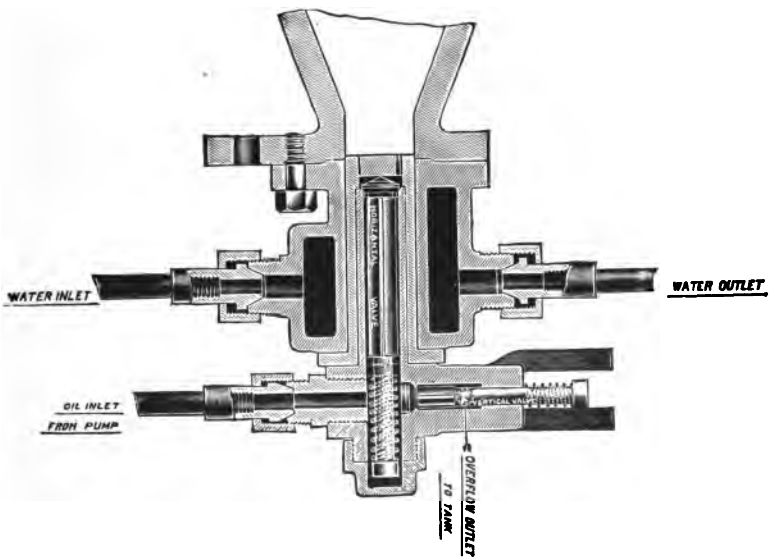


FIG. 5.

(*To face p.* 10.)

same vaporizing chamber and also by the heat generated by compression. No other means of ignition is necessary. No heating lamp is required to maintain the necessary temperature of this vaporizer; a lamp is, however, required to heat it for a few minutes before starting.

THE CROSSLEY method of vaporizing. This vaporizer is shown in section in Fig. 2. It consists of three main parts, the body, the passages, and the chimney cover. There are no valves about the vaporizer itself; it is arranged to keep hot, and while not in contact with the cooled cylinder is near to the vapor inlet valve to which it delivers its charges. The passages inside which vaporization of the oil takes place are detachable.

The wrought-iron ignition tube is placed below the vaporizer communicating directly with the cylinder. A heating lamp is always required to heat the vaporizer and maintain the ignition tube at proper red heat. The method of vaporizing is as follows:

When the suction stroke of the piston commences the oil inlet valve is automatically lifted from its seat and allows oil to be drawn into the vaporizer through it. The vaporizer blocks having been heated by the independent lamp, and likewise the chimney being hot also, heated air is drawn in passing first through the apertures in the sides of the chimney communicating with the passages of vaporizer blocks. The air is thus thoroughly heated, and next it passes over the heated cast-iron blocks. To these blocks the oil also flows from the oil measurer. The heated air here mingles with

the oil and vaporizes it, and the two together properly mixed are drawn into the cylinder through the vapor valve. Simultaneously, while the above process of vaporization is proceeding, air is also entering the cylinder through the air-inlet valve on the top of the cylinder. Thus, when the suction stroke of the piston is completed the cylinder is full of heated oil vapor drawn in through the vapor valve, too rich to explode by itself, and also atmospheric air drawn in through the air valve. Both elements are then compressed by the inward stroke of the piston completing the mixture of the oil, vapor and air. When compression is completed, ignition takes place by the gases coming in contact with the red-hot ignition tube.

THE CAMPBELL.—This method of vaporizing differs from those already described in that the whole charge of air to the cylinder is drawn in through the vaporizer. No air whatever enters the cylinder otherwise.

Fig. 3 represents the Campbell vaporizer in section. The fuel oil is fed to the vaporizer by gravitation from the fuel tank placed above the engine-cylinder, and enters the vaporizer with the incoming air. At the beginning of the suction stroke the automatic air-inlet valve is opened by the partial vacuum in the cylinder, and the oil which has entered through the small holes at the inlet valve is drawn through the heated vaporizer into the cylinder. At the compression stroke the mixture of the vapor is completed, and being forced into the ignition tube is ignited in the ordinary way. The ignition tube is heated by heating lamp fed by gravitation from the oil tank. The same lamp also heats the

vaporizer as well as the tube. The governing is effected by allowing the exhaust-valve to remain open when the normal speed is exceeded; consequently no charge is in that case drawn into the cylinder.

The method of vaporizing the oil with the PRIESTMAN engine is as follows:

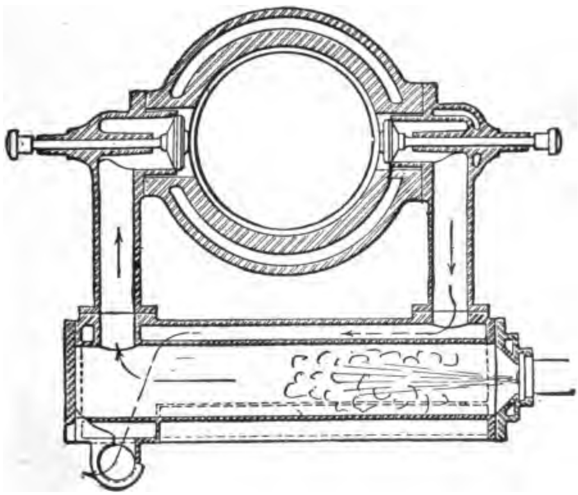


FIG. 6.

The oil is stored under pressure in the fuel-tank, which pressure is created by the separate air-pump actuated from the cam-shaft. The oil is thus forced to the sprayer, which device is shown in Fig. 7, where it meets a further supply of air. The mixing of the air and oil takes place just as both elements are injected

into the vaporizing chamber, as shown in Fig. 6. The heating of the vaporizer is first accomplished with separate lamp; afterward, when the engine is working, the exhaust gases heat the vaporizer by being carried around in the outside passage of the vaporizer cham-

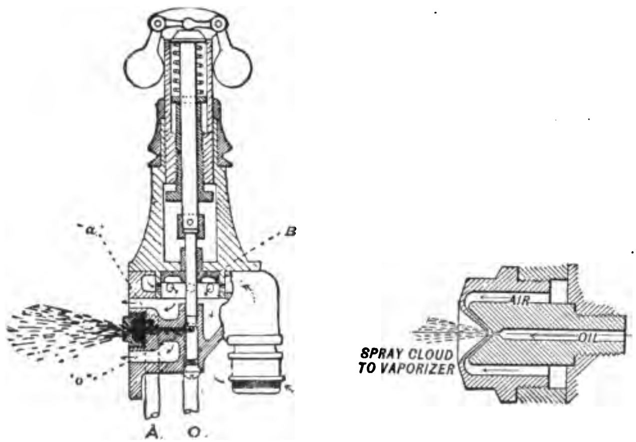


Fig. 7.

"*A*"—Air pump connection. "*a*"—Air passage to spraymaker. "*O*"—Oil tank connection. "*o*"—Oil passage to spraymaker. "*B*"—Supplementary air valve.

ber, as shown in Fig. 6. On the outward or suction stroke of the piston the mixture of oil vapor and air already formed and heated in the vaporizer is drawn into the cylinder through the automatic inlet-valve shown on the left of Fig. 6. The compression stroke

then takes place in the ordinary course of the Beau de Rochas cycle.

The governing is effected by means of the pendulum or centrifugal governor, shown at Fig. 7, controlling the amount of air entering the vaporizer as well as reducing the supply of oil simultaneously. Thus, the explosive mixture is always composed of the same proportions of air and oil, but as the supply of air is thus curtailed the compression in the cylinder is also necessarily reduced when the engine is working at half or light load. The governor thus varies the pressure of the explosion, reducing it when necessary, but not causing at any time the complete omission of an explosion.

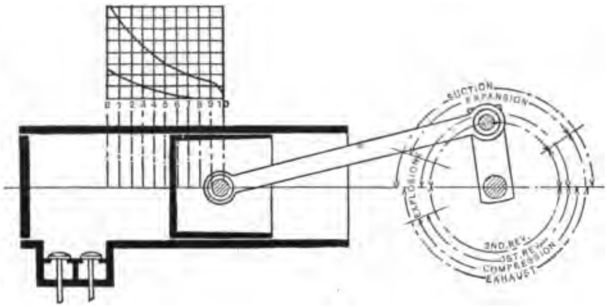
The system of throttling the pressure, somewhat similar to a steam engine, produces very steady running.

By this system a thorough vaporization of the oil takes place.

The ignition of the gases is caused by electric spark-igniter, the spark being timed by contact-pieces actuated from the cam-shaft and horizontal rod actuating the exhaust-valve, and is of the "jump-spark" type as shown in Fig. 4.

The oil engines now in use and herein described are designed with their valve mechanisms arranged to work either on the Beau de Rochas cycle, or on the two-cycle system. These two cycles are variously designated, the former being generally known as the Otto cycle, the four-cycle, and sometimes, but erroneously, the two-cycle. Correctly, it should be named the Beau

de Rochas cycle after its inventor. The other cycle is generally known as the "two-cycle," or sometimes as the "single cycle," the first designation, however, being correct. With those engines working on the Beau de Rochas cycle, which includes now many if not all the leading and best known types of engine,



THE BEAU DE ROCHAS CYCLE.

the cycle of operation of the valves is as follows:

(*a*) Drawing in the air and fuel during the first outward stroke of the piston at atmospheric pressure.

(*b*) Compression of the mixture during the first return stroke of the piston.

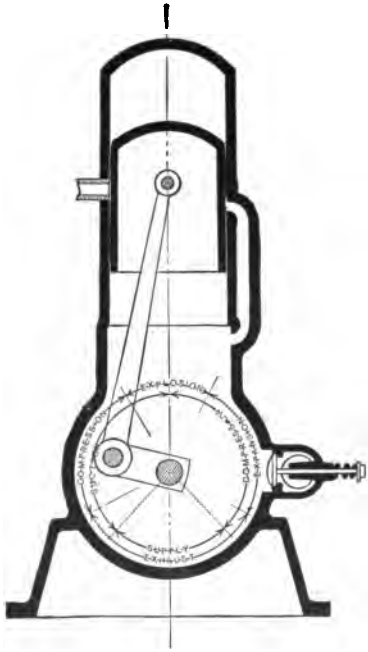
(*c*) Ignition of the charge and expansion in the cylinder during second outward stroke of the piston.

(*d*) Exhausting, the products of combustion being expelled during the second return stroke of the piston.

These operations are clearly shown in the accompanying illustration, and thus, in this system, the one cycle is completed in two revolutions of the crank-

shaft or during four strokes of the piston. The impulse at the piston is obtained only once during the two revolutions.

The second system, named "two-cycle," is com-



THE TWO-CYCLE PLAN.

pleted in one revolution, or every two strokes of the piston, and is also clearly shown by the accompanying illustration. The operation of the valves is as follows:

(*a*) During the first part of the outward stroke of the piston—that is, until the piston uncovers the exhaust-port—expansion is taking place. When the exhaust-port is opened the products of combustion are expelled; the piston then moves a little farther forward and uncovers the air-inlet port communicating with the crank chamber. The air at slight pressure at once rushes into the cylinder, assisting the expulsion of the burnt gases, and filling the cylinder with air already compressed to five or six pounds in the crank chamber; this completes the first stroke of this cycle.

(*b*) The next stroke (being the inward stroke of the piston) the supply of incoming air and fuel is first taken in; then compression of the charge takes place. Ignition follows when the piston reaches the back end. These two strokes of the piston, or one revolution of the crank-shaft, completes this cycle of operation.

Advantages and Disadvantages of Both Cycles.

The Beau de Rochas cycle engine, having only one impulse during two revolutions, requires the dimension of the cylinder to be greater in order to obtain a given power than would be required with the two-cycle system. Large and heavy fly-wheels must also be fitted to the engine in order to maintain an even speed of the crank-shaft. On the other hand, this cycle has many advantages. The explosion is controlled more readily. The idle stroke of the inlet air cools the cylinder and allows sufficient time to entirely expel the products of combustion, and with this sys-

tem no outside air-pump is required, nor is there any fear of the compression being irregular by leakage in the crank chamber or otherwise.

With the two-cycle system air must in some way be independently compressed. If this is accomplished in the crank chamber, then leakage may occur and bad combustion follow, with accompanying bad results to valves and piston. More cooling water is also needed to cool the cylinder, and the proper lubrication of the piston may consequently be very difficult to accomplish. With this system steadier running is obtained, nor are the heavy fly-wheels required as with the engines of the Beau de Rochas cycle.

Explosive engines were formerly quite extensively built to work on the two-cycle plan, either with independent air-pump or by compressing the air in the crank chamber, but as soon as the Otto patent expired a large number of engines were changed to that system. The former two-cycle engines were not economical, and when the economy of the Beau de Rochas or Otto cycle was demonstrated its superiority was quickly acknowledged.

CHAPTER II.

ON DESIGNING OIL ENGINES.

THE term "oil engine," as already stated in Chapter I., refers here only to those engines using as fuel ordinary kerosene or the crude and inferior heavy grades of petroleum of specific gravity .79 to .85, the power developed being derived from the explosion and combustion of a mixture of hydrocarbon gas and air similar to the impulse obtained in other internal combustion engines. Oil engines are similar in principle to gas engines, but as the liquid fuel must be vaporized or gasefied in an oil engine, an additional apparatus, as already fully described in the last chapter, is necessary to perform this process, which, with a gas engine, is accomplished separately and previously in the gas works or by "producer" gas plant.

The formulæ used for designing gas engines are generally applicable to oil engines also, but a greater factor of safety is sometimes allowed with the oil engine because it is possible, especially with some types of vaporizers, to occasionally have greater pressure of explosion than is ordinarily created chiefly by reason of improper combustion of the previous charge or by the governor having cut out several charges. For this

possible increased pressure, the strength of parts otherwise sufficient if of smaller dimensions are consequently increased. The formulæ herein given are derived chiefly from experience, and are believed to be in accordance with the best modern practice, and are also taken from well-known gas-engine hand-books by kind permission of the authors.

EXPLOSIVE ENGINES are of substantial design in order to withstand the continual shock and vibrations incident thereto, and should pre-eminently be as accessible as possible in the working parts, which may require adjustment from time to time when in actual service. The starting gear and other parts to be handled by the attendant when starting and running the engines incident to their operation should be placed in close proximity to each other.

Simplicity in construction is, in the writer's opinion, the essential feature of an oil engine. Above all other prime movers, the oil engine is a machine intended for use in any part of the world where its fuel is obtainable, and where, perhaps, no mechanic is available. Accordingly, all the valves should be arranged so as to be easily removed for examination and repairs. The spraying and igniting device, as well as the vaporizer, should be so designed as to facilitate removal and repairs. In short, an oil engine, to be successful mechanically and commercially, should be so constructed that it can be successfully worked, cleaned and adjusted by entirely unskilled attendants.

The mean effective pressure evolved in the different types of oil engines now in use varies from 40 to 75

lbs. The M. E. P. obtained varies, and is governed notably by the efficiency of vaporization and proper mixture of the oil vapor and air, by the pressure of compression and as the volume of clearance in the cylinder at ignition is decreased.*

With the gas engine the compression is considerably higher, being as high as 150 lbs. for blast-furnace gas and with gasoline 90 lbs. per square inch. The maximum pressure, as will be seen from the diagrams shown in Chapter IX., varies from three to five times the pressure of compression. In designing a new type of oil engine it may be necessary by experiment and with the indicator to possibly modify the estimated pressure of compression, especially with an automatic igniter of Type 4, to obtain the best results. The M. E. P. can, however, be closely approximated by reference to the different types of vaporizers described in Chapter I., and the results obtained with each as shown on diagrams in Chapter IX. The stroke is usually 1.25 to 1.6 of the diameter of the cylinder for medium and slow-speed engines, and 1 to 1.25 the diameter in high-speed engines with 800 feet per minute maximum piston speed. For an engine of a required H. P., by means of the formula on page 66, the above factors being determined, it is an easy matter to find the area of cylinder required.

Cylinders of different types are shown at Figs. 8, 8*a* and 9. Where the cylinder is made in two parts the inner liner is held at the back end only, the front joint being made with rubber ring. This arrangement leaves the inner sleeve free to expand lengthwise, and

*The formula (Prof. Grover) for gas engines M. E. P. $= 2\text{ c.} - 0.01\text{ c.}$ (c. = compression pressure) is not applicable to some oil engines.

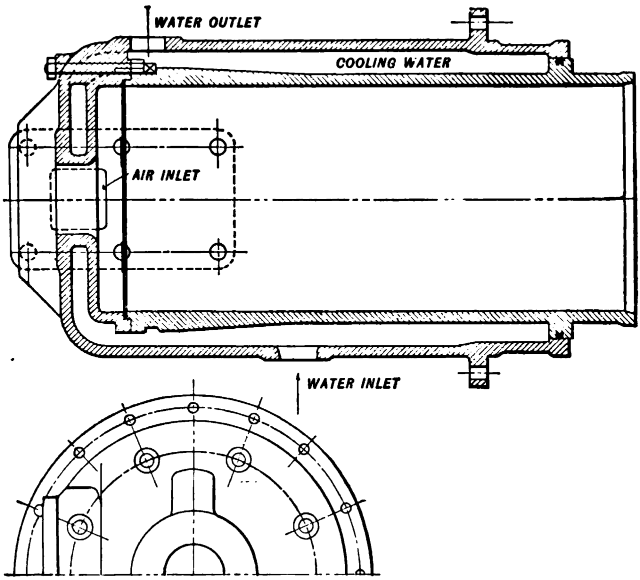


FIG. 8*a*.

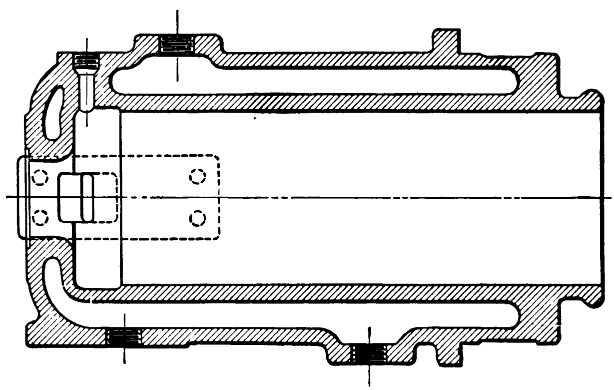


FIG. 8.

(*To face p.* 22.)

also allows the strain of the explosion to be transmitted only through the outer cylinder. Except for the larger-sized engines of over 40 H. P., the cylinder made in one piece is very satisfactory. The circulating water space around the cylinder is made as is shown in Figs. 8 and 9, being $\frac{3}{4}''$ to $1\frac{1}{2}''$ deep, the water inlet and outer pipes being so arranged as to allow free and efficient circulation of the cooling water around the cylinder. By some manufacturers this space for water is arranged to cool only that part of the cylinder covering the travel of the piston-rings, instead of the whole cylinder, as here shown. Other cylinders are cast in one piece with the frame or bed-plate having internal sleeve. This arrangement has, among other advantages, that of cheapness, but it has the disadvantage that if the cylinder for any reason should require renewing the whole frame must be renewed with it.

The cylinder cover is made in some engines with the valves, air-inlet valve housing or guide inserted into it, and with space also in the larger-sized engines arranged for cooling water-jacket. Other engines have the igniter placed in the cover, while cylinders of the type shown in Fig. 8 require no cover, the vaporizer flange closing the contracted hole in the end of the cylinder.

The cylinder in all cases should have the valves brought as close as possible to the cylinder walls, and all ports or passages so arranged as to offer the minimum amount of internal cooling surface to the hot gases of combustion.

CYLINDER CLEARANCE.—The percentage of clear-

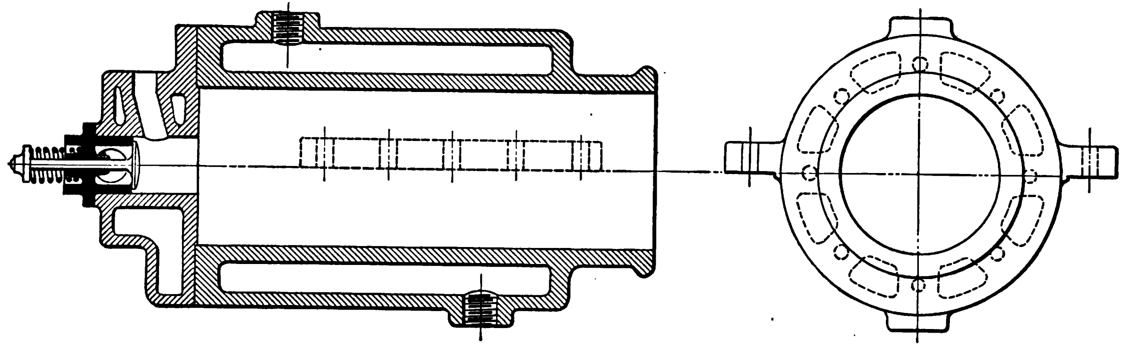


Fig. 9.

ance in the cylinder is ascertained by dividing the total clearance in the cylinder, including all ports or other spaces, by the piston displacement.

The clearance allowed will depend upon the pressure of compression as determined by experiment and by the indicator diagram, producing properly timed ignition and combustion.

This pressure, it will be noted, on referring to the various indicator cards shown herein, now varies in different types of engines from 50 to 70 pounds, which it is believed is representative of present practice, with the exception of the Diesel motor, which engine compresses to over 500 pounds before combustion takes place in the cylinder. This exceedingly high compression is rendered possible by the special Diesel system of injection of the charge of fuel.

The fuel in this case enters the cylinder only at the extreme end of the stroke of the piston, the compression period being then completed.

THE CRANK-SHAFT of an oil engine must be made of sufficient strength not only to withstand the sudden pressure due to ordinary explosion, but also to withstand the strain consequent upon the greater explosive pressure which may possibly be caused by previous missed explosions, as already described. The crankshaft is proportioned in relation to the area of the cylinder and the maximum pressure of explosion and the length of stroke. Oil-engine crank-shafts are usually made of the "slab type," as shown in Fig. 10. It has been said with regard to explosive engines that their comparative efficiency may be to a certain extent

gauged by the strength of the crank-shaft, because if the crank-shaft is of too small dimensions, it will spring with each explosion, causing the fly-wheels to run out of truth and also uneven wear of the bearings. Table I. gives a list of dimensions of crank-shafts of both oil and gas engines which are made by some leading manufacturers, together with the dimensions of the cylinder and stroke.

Different formulæ for the dimensions of crank-

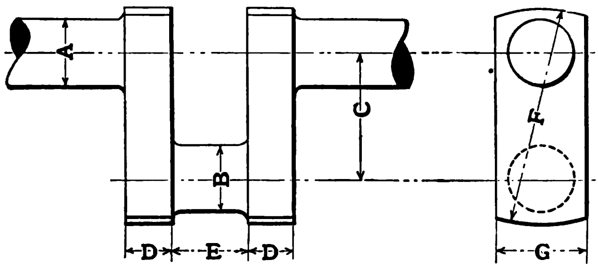


FIG. 10.

shafts are given by various writers on this subject. The following, for example (which is recommended by the writer), is given by Mr. William Norris.

$$D = \sqrt[3]{\frac{S \times l}{120}}.$$

S = load on piston (area of cylinder in inches $\times$ maximum pressure of explosion.
l = length of stroke in feet.
D = diameter of crank-shaft in inches.

This formula, however, neglects the bending action due to the distance of the centre of crank-pin from the centre of the bearings. The diameter should be thus slightly increased. Mr. Norris also gives a lengthy description, with example, of ascertaining all the dimensions of the crank-shaft by means of the graphic method.

TABLE I.—SIZES OF CRANK-SHAFTS.

Cylinder.		A.	B.	C.	D.	E.	F.	G.
Diam.	Stroke.	in.	in.	in.	in.	in.	ft. in	in.
5	8	$1\frac{3}{4}$	$1\frac{7}{8}$	4	$1\frac{1}{2}$	2	$6\frac{1}{2}$	$2\frac{1}{2}$
$5\frac{3}{4}$	9	$2\frac{1}{4}$	3	$4\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{5}{8}$	$8\frac{1}{2}$	$3\frac{1}{2}$
$7\frac{1}{2}$	11	$2\frac{3}{4}$	$3\frac{1}{4}$	$5\frac{1}{2}$	$2\frac{3}{8}$	3	$9\frac{1}{2}$	$4\frac{1}{2}$
$8\frac{1}{2}$	15	$3\frac{1}{4}$	4	$7\frac{1}{2}$	$2\frac{7}{8}$	$3\frac{1}{2}$	$12\frac{1}{2}$	5
$8\frac{1}{2}$	18	$3\frac{1}{4}$	4	9	3	$3\frac{1}{4}$	1 2	5
$9\frac{1}{2}$	18	$3\frac{1}{2}$	$4\frac{1}{4}$	9	$3\frac{3}{8}$	$3\frac{1}{4}$	1 3	$5\frac{1}{2}$
12	18	$4\frac{1}{4}$	$4\frac{3}{4}$	9	$3\frac{3}{4}$	$4\frac{1}{2}$	1 $3\frac{1}{4}$	$6\frac{1}{4}$
$11\frac{1}{2}$	21	$4\frac{1}{4}$	$4\frac{3}{4}$	$10\frac{1}{2}$	4	$3\frac{1}{2}$	1 $3\frac{1}{2}$	$6\frac{1}{2}$
14	21	$5\frac{1}{2}$	$5\frac{3}{8}$	$10\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{4}$	1 5	$8\frac{1}{2}$
17	24	7	8	12	$5\frac{3}{4}$	$7\frac{1}{2}$	1 $10\frac{1}{2}$	10
19	30	$7\frac{1}{2}$	8	13	6	9	2 2	11
7	12	$2\frac{7}{16}$	$2\frac{5}{8}$	6	$2\frac{3}{16}$	$2\frac{5}{8}$	$8\frac{3}{4}$	$3\frac{3}{4}$
9	14	$2\frac{15}{16}$	3	7	$2\frac{1}{4}$	$3\frac{3}{8}$		4
11	15	$3\frac{7}{16}$	4	$7\frac{1}{2}$	$2\frac{9}{16}$	$4\frac{1}{8}$	$12\frac{1}{8}$	$4\frac{5}{8}$
$13\frac{1}{2}$	16	$3\frac{15}{16}$	$4\frac{7}{8}$	8	$3\frac{9}{16}$	$4\frac{7}{8}$	$13\frac{3}{8}$	$5\frac{3}{8}$

THE BALANCING of crank-shafts and reciprocating parts is another important feature of an oil engine. With a single-cylinder explosive engine to perfectly accomplish the balancing is impracticable. Most manufacturers, therefore, only balance their engines as far

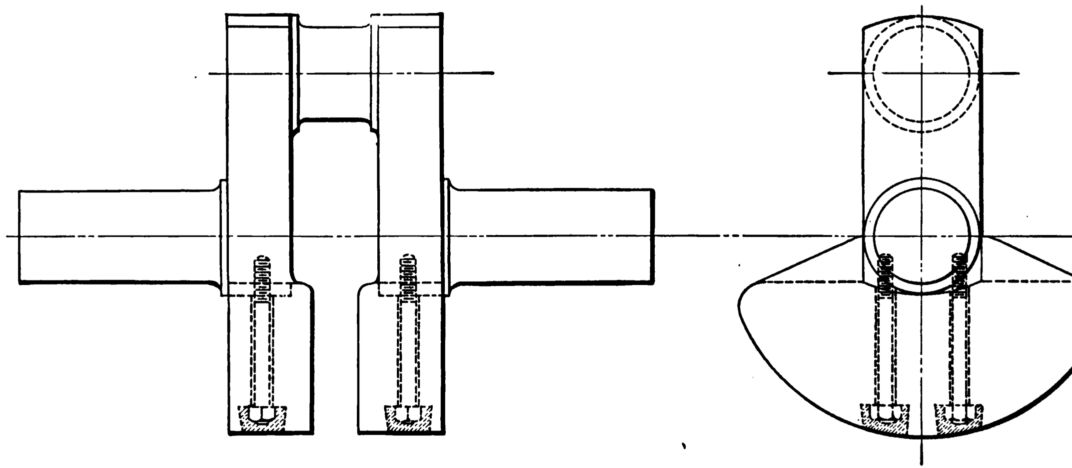


FIG. 11.

as the horizontal movement is concerned. The following formulæ is considered correct, and has proved satisfactory for the horizontal type of engines:

$$w = \frac{(C \times R) + G + (S \times r)}{a}.$$

w = weight in lbs. of balance weight.
C = crank-pin and rotating part of connecting-rod in lbs.
R = radius of crank circle in inches.
G = two-thirds weight of all remaining reciprocating parts in lbs.
S = weight of crank-arms in lbs.
r = distance of centre of gravity of crank-arms from centre of rotation.
a = distance of centre of gravity of counterweight from centre of rotation.

Some designers, however, the writer has observed, make the crank balance weights as large as space between bearings and engine bed will allow—that is, when the weights are fastened to the crank-arms, as shown in Fig. 11, thus overbalancing the crank and reciprocating parts. While this would appear bad practice, such engines have been known to run without the slightest vibration. For the vertical type of engines the whole weight of the reciprocating parts, instead of two-thirds weight, has been satisfactorily taken.

Crank-shafts of explosive engines are sometimes balanced by metal suitably placed on the rim or hub of the fly-wheel; otherwise some wheels are made with recess

left in rim placed just in line with crank-pin, so that the metal left out of the rim of the fly-wheel will equalize the metal which is contained in the crank-pin and other parts to be balanced. Balancing by means of the recess at the outer radius of the fly-wheel has the advantage of requiring no extra metal, and is cheaper as regards workmanship as compared with the system as shown in Fig. 11. In each of these methods, however, the fly-wheel itself is out of balance, and when revolving tends to make the crank-shaft run out of truth.

The more expensive method of placing balance weights on the cheek of the crank-shaft itself, as shown in Fig. 11, is considered by the writer the most satisfactory method. In this way the crank-pin and reciprocating parts are themselves separately balanced regardless of the fly-wheels, and the fly-wheel being itself also balanced, when running allows the crank-shaft to remain absolutely true. Further, it is also advantageous to core small recesses in the fly-wheel rim, to be filled up, if required, with lead so as to exactly balance the wheel should it, from inequality in casting, be heavier in one part than in another. This, however, is only requisite in special cases, or where the engine is running at a very high rate of speed.

Connecting-rods are made of various designs in cross-section, but that chiefly used is made of soft steel and circular, with marine type brasses at crank-pin end and similar bearings at the piston or small end. By some makers the latter bearing is made with adjustable wedge and screw, the end of the connecting-rod

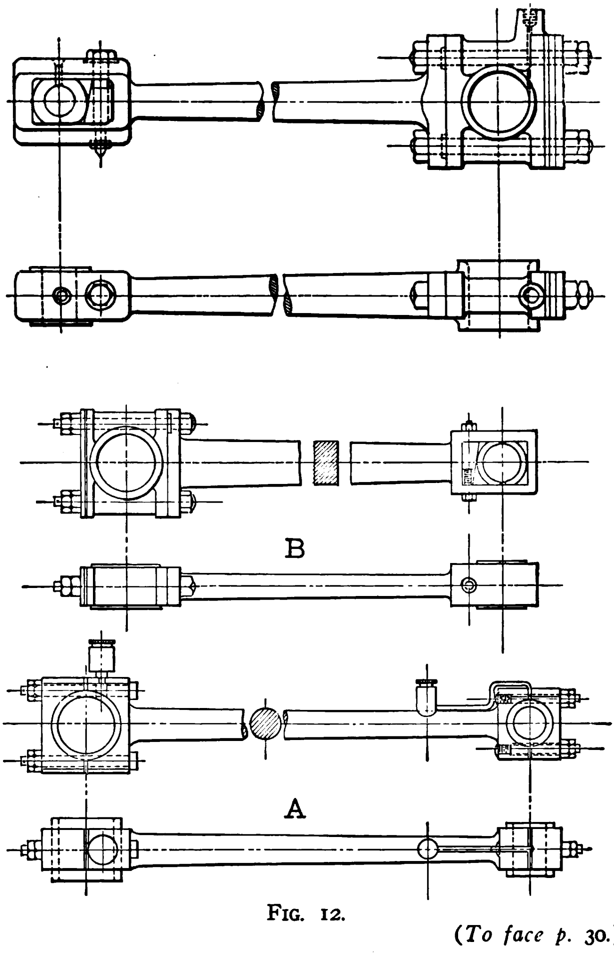


FIG. 12.

(To face p. 30.)

then being slotted out, with brass bushes fitted into it.

Each type of connecting-rod is shown at Fig. 12. That illustrated at "A" is a design more suitable for the larger size engines, in which space inside the piston is available for adjustment of the bolts, as shown. The connecting-rod marked "B" is of the rectangular type, and is frequently left rough, the ends only being machined. The piston or small end brasses are proportioned to allow an average pressure of 750 lbs. per square inch of projected area, the bearings on the large or crank-pin end being proportioned to suit the crank-pin, as stated on page 43.

The crank-end bolts should be proportioned having an area at least .25 of the mean area of the rod, according to the formulæ following:

The rectangular type of rod, when made of mild steel, should contain an area 30% greater than the circular type; the width of the rod is recommended, being 1.80 its thickness.

For small engines a good and cheap form of connecting-rod is made of phosphor-bronze metal, as shown in Fig. 13, from which it will be seen that the piston-end bearing is made in one piece with the rod, and being slotted is thus made adjustable. The metal is left rough other than at the bearings.

The connecting-rod of a single-acting engine has, chiefly, compression strains to withstand; both the outer end bearings have little or no strain on them, except that due to momentum of the reciprocating parts. The connecting-rod should be from two to

three strokes in length. In computing its strength, the connecting-rod can be taken as a strut supported

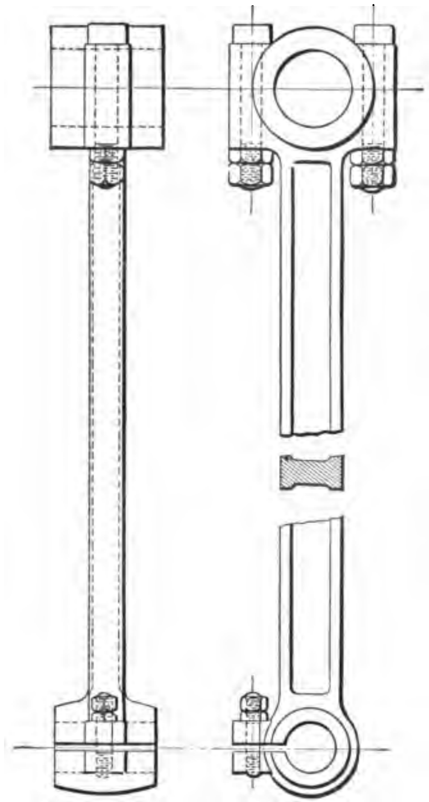


FIG. 13.

at either end. The mean diameter when made of mild

steel is arrived at by the following formulæ, as given by authorities on steam-engine design:

$$x = 0.035 \sqrt{D\, l \sqrt{m}}.$$

x = mean diameter of connecting-rod (half sum of diameter of both ends).
D = diameter of cylinder in inches.
l = distance in inches between centre of connecting-rod.
m = maximum explosive pressure in lbs. per square inch.

This formula, however, is excessive for medium and slow speed engines, and in such instances the writer has used the following formulæ with satisfactory results—namely:

$$0.028 \sqrt{D\, l \sqrt{m}}.$$

THE PISTON in single-acting engines is generally of the trunk pattern, as shown in Fig. 14, with internal gudgeon-pin placed in the centre of the piston, secured at either end to the piston by set-screws. The steam-engine cross-head and slide-bars are dispensed with, the power being transmitted directly from the gudgeon-pin of the piston to the crank.

The piston is made of hard close-grained iron, and should not be less than 5-16″ in thickness for small engines and slightly heavier for the larger sizes. In

each case the metal is thicker at the back than at the front end. The piston is usually 1.6 diameters in length. Three cast-iron piston-rings, as shown in Fig. 15, are fitted to the smaller engines, four and five rings being required to keep the piston tight in the larger sizes. A single ring is sometimes added, placed in front of the gudgeon-pin, but its use is not recommended. The pressure on the piston, caused by the explosive pressure and due to the angularity of the connecting-rod, should not be greater than 25 lbs. per square inch of rubbing surface.

The piston in which separate distance-pieces between each ring and having separate plate bolted to the back of the piston is shown at Fig. 14*a*.

In the larger engines the piston is water-jacketed; that is, a chamber at the back end is supplied with water, as shown in Fig. 95. The water is conducted to and fro by separate pipes moving with the piston and communicating through stuffing-boxes with chambers containing the water. The piston in the larger engines exposed to an increased volume of the burning gases would, if not water-jacketed, become overheated and unduly expanded and further proper lubrication could not be maintained without it.

PISTON SPEED.—The speed of the piston for horizontal oil engines is usually allowed to be not greater than 800 feet per minute (600 feet is preferred by many). The movement of the valves, oil-spraying and vaporizing devices, renders very high speeds undesirable. The writer has, however, operated a 1½ H. P. vertical oil engine running at

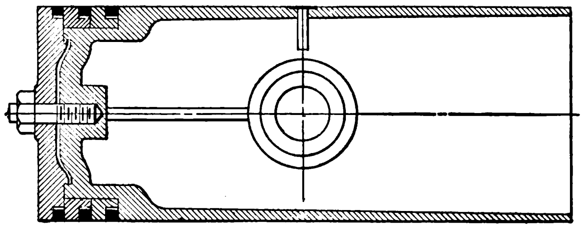


FIG. 14*a*.

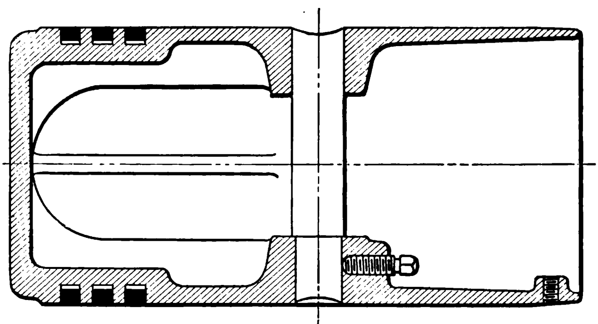


FIG. 14.

(*To face p.* 34.)

600 revolutions per minute with satisfactory results. Thus, 300 movements of the valves, oil-pump and sprayer were completed per minute.

FLY-WHEELS on explosive engines are made much heavier than in steam engines of the same capacity.

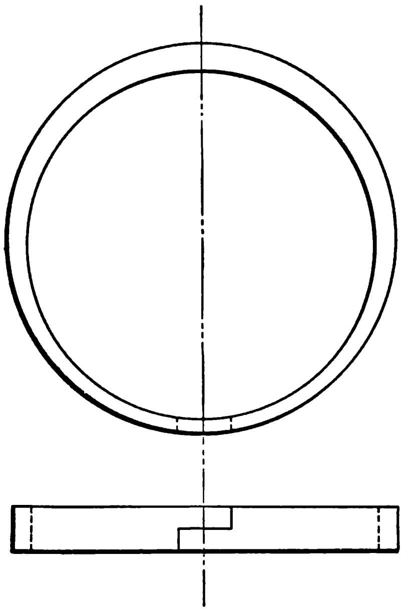


FIG. 15.

The power is generated during only about twenty-five per cent. of the time of working in single-cylinder four-cycle explosive engines, hence the necessity of the very heavy fly-wheels in order to maintain a steady speed of the crank-shaft. The function of the fly-

wheel, it may be said, is to store up the energy imparted during the explosion period and pay it out again during the period of the three idle strokes of compression, suction and exhaust. Two fly-wheels are generally supplied, one placed on each side of the main bearings. Some of the European makers, however,

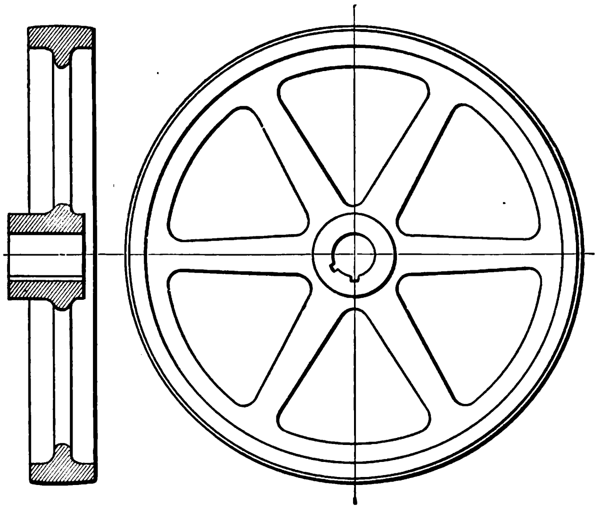


FIG. 16.

are now building their larger engines provided with one heavy fly-wheel only, a separate outside bearing being fitted in that case.

The diameter of the fly-wheel is usually such that the peripheral speed is from 4000 to 5000 ft. per minute; 6000 ft. is considered the maximum allowable speed.

The hub of the fly-wheel is sometimes split and bolted together. Oil-engine fly-wheels are usually made as shown in Fig. 16. The weight of the rim can be calculated as follows:

$$w = \frac{C \times \text{I. H. P.}}{D^2 \times N^3},$$

where

C = constant.
I. H. P. = indicated horse-power.
D = diameter of fly-wheel in feet.
N = revolutions per minute.
w = weight in lbs. of rim.

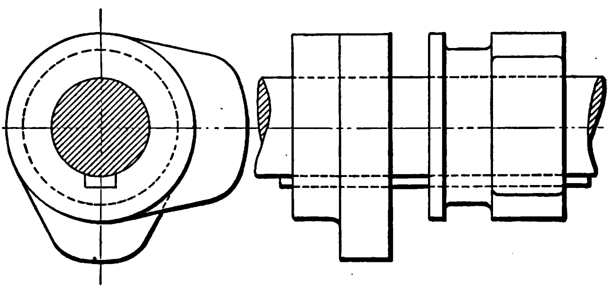


FIG. 17.

The constant varies according to the fluctuation in speed permissible; for engines required to run dynamos for electric lighting purposes, $C = 50,846,290,000$. For engines actuating general machinery C is considered sufficient when taken as 30,507,700,000.

The cams are made of cast iron or steel and are usually designed as shown in Fig. 17. Cast iron is ad-

vantageously chilled to withstand the wear of the rollers.

The function of a cam is to transfer rotary motion of the crank-shaft and cam-shaft to the reciprocating action required for lifting the poppet valves. The rapid opening and closing of the valves necessary in a four-cycle engine is more easily arrived at with a cam motion than otherwise. The valve is closed by a spring, the function of opening the valve being performed by the cam only. Generally valve mechanisms in which cams and poppet valves are used are noisy in operation, especially in higher speed engines.

The rate of opening and closing of the valve can be ascertained by plotting a curve corresponding to ordinates equivalent to the various distances from the face of the cam to its centre taken at specified intervals. The required width of the face of the cam in contact with the rollers is ascertained by computing the work to be done due to the pressure in the cylinder at time of valve opening, together with the area of the valve. Accordingly, where the air valve is operated the cam controlling its movement is of less width, seeing that only atmospheric pressure obtains when it is operated as compared with the exhaust valve cam, which has to open that valve against a pressure in some cases as high as 40 lbs., necessarily involving considerable work.

VALVES AND VALVE-BOXES.—The dimensions of the air-inlet and exhaust valves are governed by the diameter of the cylinder and the piston speed. The style of the valve-box recommended is that made separate and bolted to the cylinder. The valve-box can then

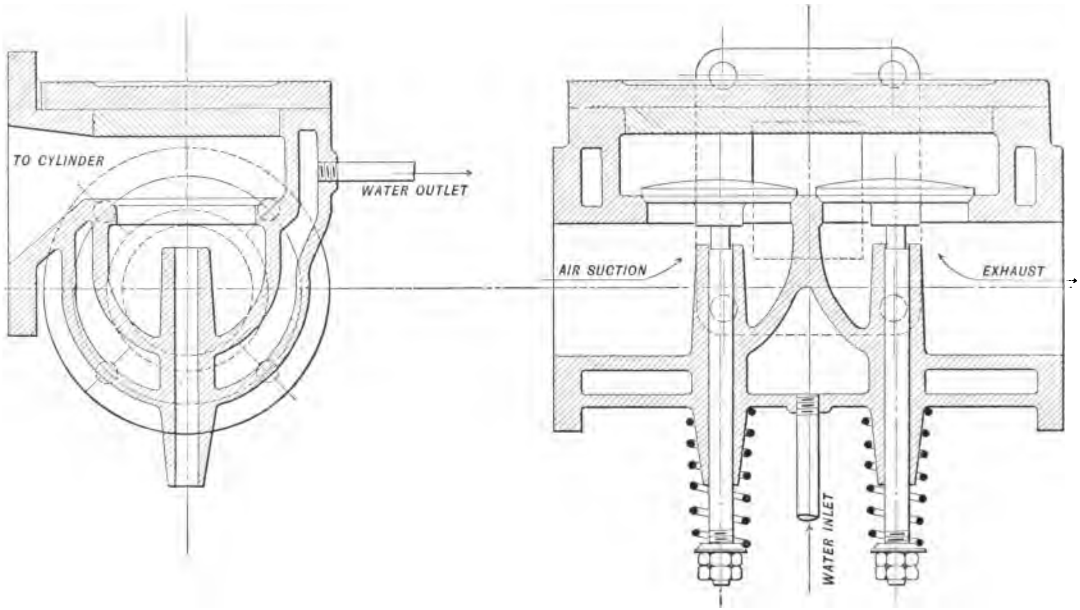


FIG. 18.

(*To face p.* 38.)

be entirely renewed if necessary and at small expense. This type of valve-box is shown at Fig. 18, both valves being operated from the cam-shaft. The springs required to close the valves are shown at Figs. 18 and 19. The latter arrangement has the advantage of having the springs placed away from the heated valve chambers. Other designs of valve chambers have the valves placed horizontally in the cylinder back-head. A compact design of valves is shown at Fig. 20, in which the exhaust valve is operated only, the air valve being automatic. In each case the valves should be brought as close as possible to the cylinder walls, the clearance space in the ports, etc., being reduced to a minimum.

With engines of larger size the air and exhaust valve box is surrounded by a water jacket, which maintains its proper temperature and prevents the seats of the valves being distorted by undue expansion, which might otherwise occur. It will be noted in the illustration that the inlet and outlet water connections to the valve-box are made by separate pipes.

Where the air-inlet valve is made automatic, it is opened by the partial vacuum in the cylinder during the suction period, and closed by a delicate spring, as shown in Fig. 20. The air and exhaust valves and port openings are usually made of such an area that the velocity of the air inlet as it enters the cylinder is 100 feet per second—the velocity of the exhaust gases through the exhaust or outlet being about 80 feet per second, presuming the exhaust products to be expelled at atmospheric pressure. The air-inlet valve, if automatic, should be so arranged as to allow ingress of air

without choking. In calculating the area of valve ports or passages, allowance must be made for valve

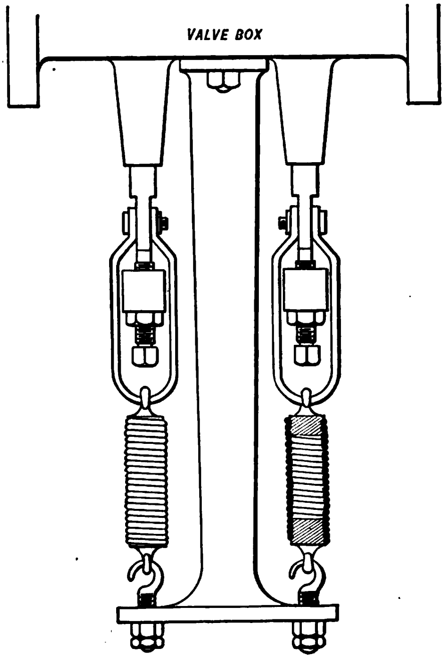


FIG. 19.

guide or other obstruction in the passages. The velocity of the air is found in the following formulæ:

$$V = \frac{a \times P}{a_1}.$$

V = velocity of air in ft. per second.
P = piston speed in ft. per second.
a = area of piston in inches.
a_1 = area of valve opening in inches.

THE EXHAUST BENDS close to valve-box should when possible be of not less than 5″ radius for the

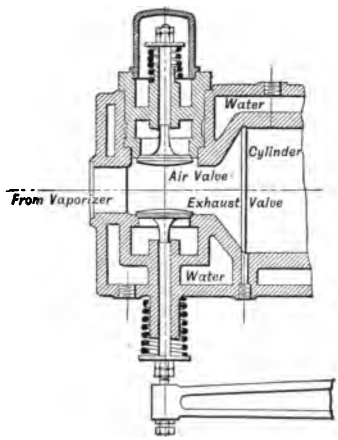


FIG. 20.

smaller engines, which dimension should be increased for larger-sized engines.

The valves are made of forged steel, either in one piece or with cast-iron valve and wrought-iron or steel stem fitted into it, and are shown in Fig. 21. Some manufacturers prefer the latter on account of cheapness, and also because it is claimed the cast-iron valves will withstand heat better than the forged valve.

THE CRANK-SHAFT bearing should be of such dimensions as to allow a pressure of not more than 400 lbs. per square inch on the projected area, and should be easily adjustable. These bearings are made either of brass or babbitt metal. The maximum pres-

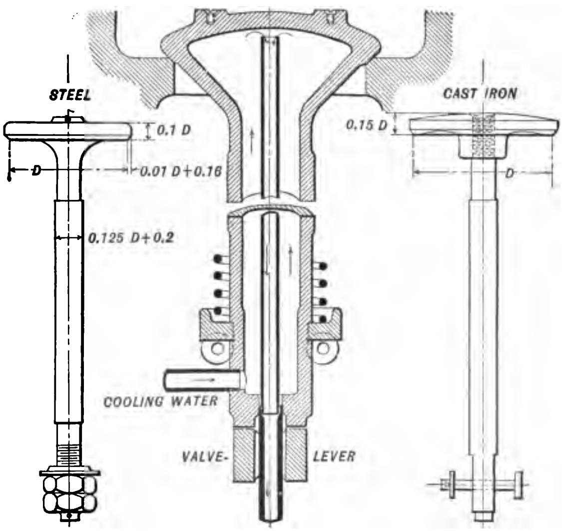


FIG. 21.

sure allowed on the piston-pin should not be more than 1000 lbs. per square inch of projected area.

THE ENGINE FRAME should be of substantial proportions and strongly ribbed to prevent vibration, or what is known as "panting," at each explosion. The frame is shown in section in Fig. 76.

THE CRANK-PIN appears to be made of various

dimensions in different types of engines; a short pin of large diameter is, however, recommended, the diameter being not less than 1.2 times the shaft. (See Table I.) The average pressure allowed is 500 lbs. per square inch on the projected area.

VALVE MECHANISMS.—With the Beau de Rochas or four-cycle engine the valves are only operated during alternate revolutions of the crank-shaft. This necessitates an arrangement of some kind of two-to-one gear. Worm-gear, as shown in Fig. 22, is considered

FIG. 22.

to be well adapted for this work. The power necessary to operate the valves is, in this case, transmitted from the crank-shaft by the worm or skew gearing through the cam-shaft, with separate cams opening the air and exhaust valves by the operating levers, as shown in Fig. 23. Where spur-gearing (Fig. 23*a*) is used the cam-shaft is mounted in bearings parallel to the crank-shaft, the cams then acting on the horizontal rod working in compression, which opens the valves.

Various other arrangements for reducing the motion are also used, the work accomplished being in each

case the same as with the worm or spur gear, shaft and levers—namely, the opening of the valves during alternate revolutions of the crank-shaft.

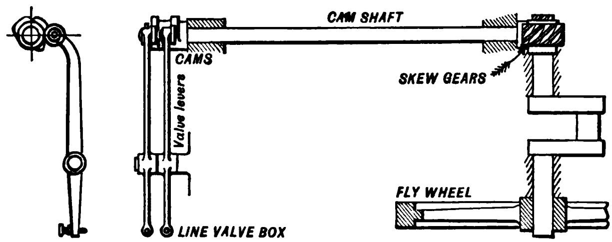


FIG. 23.

In the two-cycle engine this valve or valves are operated each revolution of the crank-shaft by eccentric or cams actuated directly from the crank-shaft.

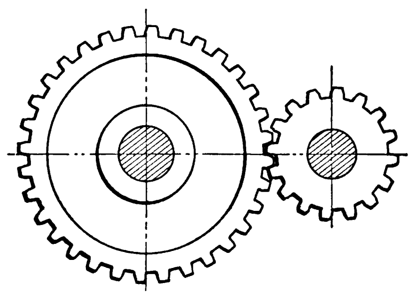


FIG. 23*a*.

GOVERNING DEVICES.—The governing devices for controlling the speed of oil engines are of two kinds: first, that designed to develop centrifugal force, which

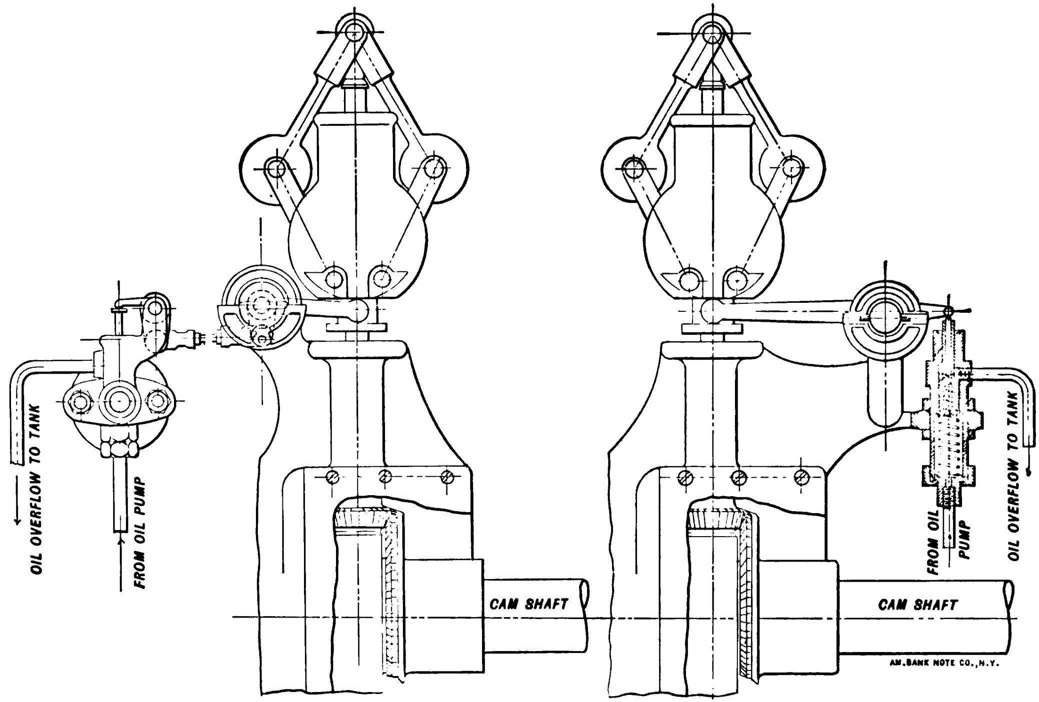


FIG. 24.

(To face p. 44.)

is balanced either by suitable controlling spring or dead weight, as shown in Fig. 24, and, secondly, the inertia or pendulum type of governor.

The accompanying illustrations also show the method of by-passing the oil where the air supply is constant at all loads. The Rites governor, a very simple and efficient device of the fly-wheel type of governor, is illustrated and described in Chapter X., the method of governing, in which the air supply and oil supply is controlled, is shown at Fig. 7, illustrating the Priestman governor. In those engines where the regulation is controlled by preventing the suction into the cylinder, caused by holding the exhaust valve open, the inertia type of governor is sometimes used, where the inertia of a weight attached to a reciprocating part of the valve motion is arranged, having its movement controlled by an adjustable spring. When the normal speed is exceeded the inertia of the weight overcomes the pressure of the spring and thus holds open the exhaust valve till the normal speed is regained.

The governors regulate the speed of the engine by the following different methods:

(*a*) By acting through suitable levers or other mechanism on the valves controlling the fuel supply to the cylinder, either by means of a by-pass valve placed in the oil-supply pipe to vaporizer, thus allowing part of the charge of oil to return to the tank instead of entering the vaporizing chamber or by regulating the amount of oil as well as the air supply.

(*b*) Acting directly on the oil-supply pump, length-

ening or shortening the stroke of the pump, as required.

(*c*) Where the oil vapor is arranged to be drawn into the cylinder with the incoming air the governor

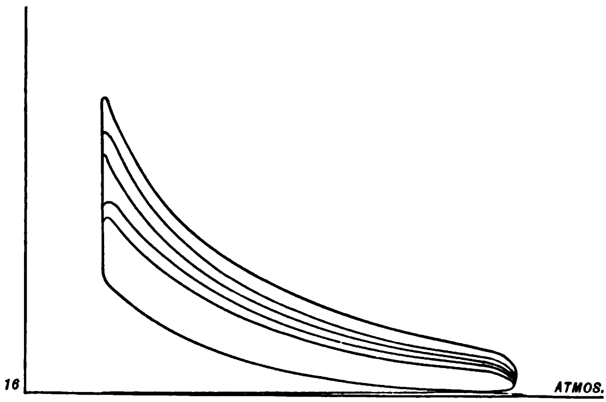


FIG. 25.

acts on the exhaust-valve, holding it open during the suction stroke, thus preventing the inlet of vapor to the cylinder.

(*d*) By acting on the vapor inlet-valve, allowing this valve to open only when an impulse to the piston is required.

Engines driving dynamos for electric lighting and requiring very close regulation are preferably governed by the system of throttling or reducing the explosive pressures in the cylinder. Thus, when the engine exceeds the standard speed for which the governor is set, only part of the vapor or oil is allowed to enter the

vaporizing chamber or cylinder. The mixture of oil,

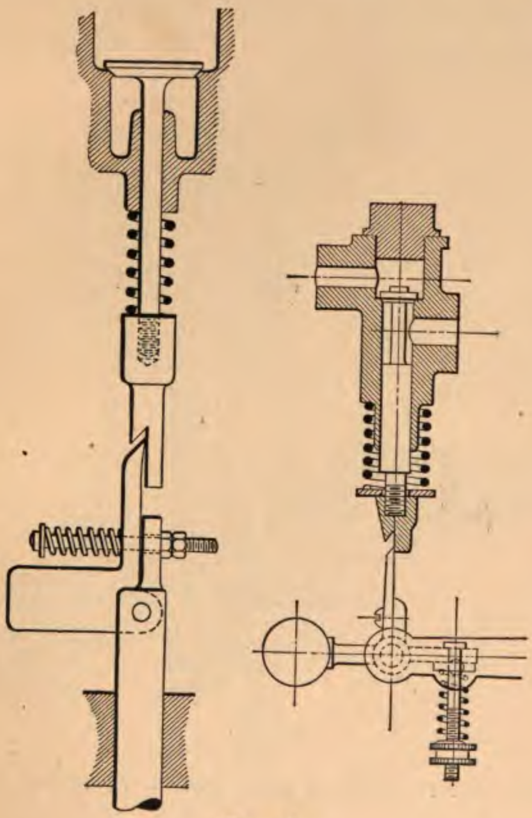


FIG. 26.

vapor and air is accordingly regulated, and the mean effective pressure as required is suitably reduced.

The indicator diagram illustrates the variation of the M. E. P. in the cylinder, as shown in Fig. 25, each expansion line registering a different pressure. No explosion is in this case omitted entirely, and conse-

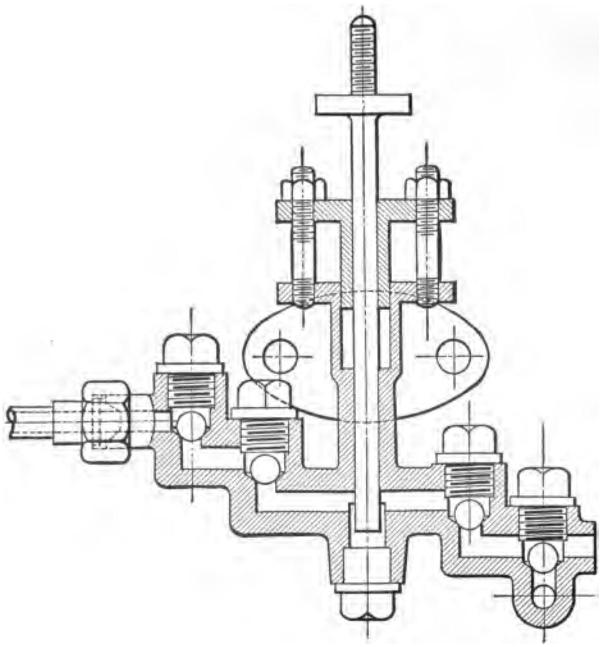


FIG. 27.

quently the running of the engine is even and regular.

The hit-and-miss type of governor is shown in Fig. 26. This device is made in many different forms, the mode of working being similar in them all—namely,

the inertia of a weight controlled by the spring. When the speed of the crank-shaft is increased the weight is moved correspondingly quicker; its inertia is then increased, and the strength of the spring is overcome sufficiently to allow the engaging parts of the valve motion to be disengaged during one or more revolutions, and consequently where this device acts on the oil-pump the charge of oil is missed, and no explosion takes place during the following cycle of operations.

THE OIL-SUPPLY PUMP is placed against the oil-tank and base of engine or on bracket bolted to cylinder. It is usually made of bronze, with steel ball valves. Duplicate suction and discharge valves are advantageous in case one valve on either side should leak. Fig. 27 represents oil-pump as used on the Hornsby-Akroyd oil engine.

THE FUEL OIL-TANK is placed in or bolted against

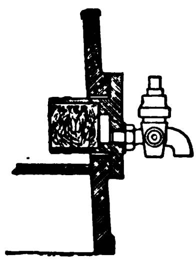


FIG. 28.

the base of the engine. It is then made of cast iron as part of the base of the engine; otherwise the tank is made of galvanized iron and separate from the engine

base, so that it can be taken out when required for cleaning.

A filter or strainer for cleaning the oil as it passes to the oil-pump is placed in the tank, arranged so as to be easily removed for cleaning, as shown at Fig. 28.

Horizontal as Compared with the Vertical Type of Oil Engines.

The accessibility of the piston with the horizontal engine is considered a great advantage. The piston can always be seen and can be drawn out of the cylinder and cleaned and replaced with ease in this style of engine, whereas in a vertical engine it is necessary to remove the cylinder cover, and perhaps other parts, to gain access to the piston, and also it is necessary to have sufficient head room above the top of the cylinder for chain-block to lift the piston and connecting-rod. The lubrication of the piston is also considered more effective in the horizontal than in the vertical type of engine. Furthermore, the connecting-rod is more accessible for adjustment both at the crank-pin end and at the piston end in the horizontal type. This difficulty, however, has been overcome by arranging a removable plug in the cylinder casing, which when taken out allows access for adjustment to the piston end of the connecting-rod. European designers seem much in favor of the horizontal type of engines, and although some leading makers build the vertical type of engines, yet the greater number would appear to be made of the horizontal type.

Vertical engines for situations in buildings where space is restricted and where sufficient head room is available have the great advantage of occupying less floor space than the horizontal type. The mechanical efficiency of a vertical engine is somewhat greater, the friction of the piston being less than in the horizontal type of engine.

The vertical type for some special purposes can, of course, only be used, but for ordinary uses the horizontal type of engine at present seems to be most in favor, one consideration being the difficulty of suitably arranging the vaporizing and spraying details in the vertical type of engine, which are usually placed close to the cylinder, and are, therefore, not so fully under the control of the attendant as in the horizontal type.

Two-Cylinder Engines.—Objection is sometimes made against two-cylinder oil engines because of the increased number of working parts, which may possibly become deranged, and also because of the exact adjustments which are considered necessary.

The oil-supplying apparatus and all the mechanism required with a single-cylinder engine has to be duplicated with the two-cylinder type. In order that the work and wear on all crank-shaft and connecting-rod bearings may be exactly similar the same explosive pressures must be evolved in each cylinder. This necessitates close adjustment of the vapor supply. The governing mechanism (where one governor controls two different oil-supply devices) also requires fine ad-

justment, and provision has to be made for adjusting lost motion due to wear.

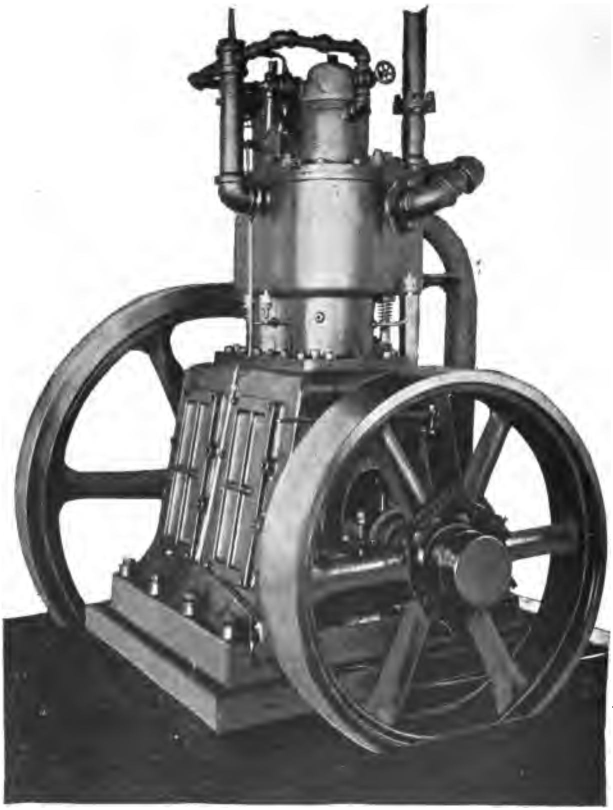


FIG. 29.

The two-cylinder engine, however, has many ad-

vantages. In the first place, it receives an impulse each revolution of the crank-shaft, and consequently the energy of the fly-wheel is only required to maintain the normal speed of the crank-shaft during half a revolution, instead of the three strokes as required in the single-cylinder type. To obtain relatively the same power as with one large cylinder, the two smaller cylinders cause less vibration at the foundation. The efficiency, however, of the two small cylinders is reduced as compared with the one large cylinder, on account of the increased surface of cylinder cooling space.

The two-cylinder engine, as shown in Fig. 29, has the oil-supply pump actuated from the crank-shaft instead of, as is usual, from the cam-shaft, an injection of oil thus being given at each revolution. The oil-supply pipe leading to each cylinder or vaporizer is fitted with check-valves, which are alternately opened by the pressure of the pump, being otherwise held closed by the pressure of compression and of explosion alternately in each cylinder.*

Erecting and Assembling of Oil Engines.

The following remarks relating to the erection of oil engines contain a few hints on important points of this work, the information being intended for those

* This method of fuel injection forms the subject-matter of U. S. patent 650,583, granted to the writer May 29, 1900.

readers not sufficiently familiar with the assembling of explosive engines to be cognizant of the parts requiring careful handling and accurate workmanship.

Bearings.—In scraping in the crank-shaft bearings of horizontal engines the shaft must bear perfectly on that part of the bearings as shown in Fig. 30, marked

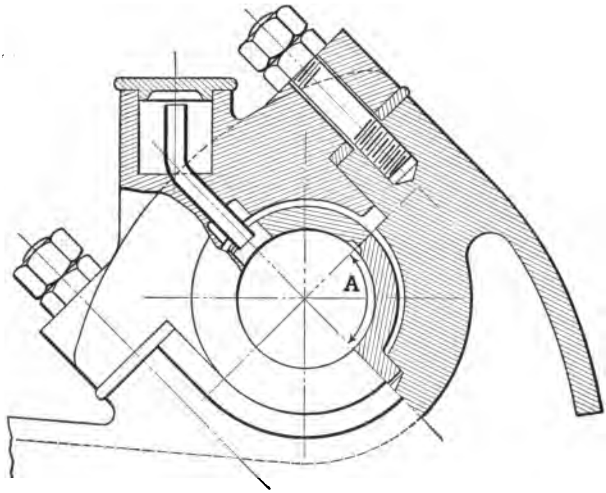


Fig. 30.

A, the greater pressure being on the part of the bearing which is between the centre line of engine drawn through the cylinder and the part through which the vertical centre line of fly-wheel is drawn. A slight play of about 1-64″ can be given to the crank-shaft sideways in the bearings in smaller-sized engines, and 1-32 of an inch in the larger sizes is recommended.

In vertical engines the bearings receive both the pressure of explosion and the pressure due to the weight of the fly-wheels in the same part, and these bearings require the same care at those points in the lower half of the bearing—namely, about 45° each side of the centre line drawn vertically through the cylinder and crank-shaft. The bearing surfaces of the caps and of that part where the pressure is not so great do not require such careful scraping as those parts where the pressure is greater.

PISTON AND PISTON-RINGS.—The fitting of piston and piston-rings is very important and requires accurate workmanship. The cylinder and piston are machined to standard ring and gauge, one-thousandth per inch diameter of cylinder play being allowed. The metal of the piston not being of uniform thickness after machining may slightly lose its shape, and sometimes requires slight hand-filing when being fitted to the cylinder. The piston without rings can be moved easily up and down inside the cylinder. If necessary the piston should be eased slightly by hand on the sides, being left a good and close fit at the top and bottom bearing in horizontal engines. The sides should not rub hard in any part. The piston, if the rings are in place, can be fitted to the cylinder from the back end of the cylinder, and can be moved around the front end, being inserted into cylinder as far as the rings.

THE DISTANCE-PIECES or junk-rings should not touch the sides of the cylinder, the bearing of the piston being only on the trunk of the piston itself. The front

part of the piston can also be bevelled for ¾″ in length, 1-32″ in diameter, as shown in Fig. 14.

THE PISTON-RINGS, if made as in Fig. 15, should have in the smaller sizes 1-32″ play, in the larger sizes 1-16″, as shown at *A* in Fig. 31. This space allows for expansion when the ring becomes heated in working. It is advantageous to insert dowel-pins in the piston grooves to maintain the rings in the same position, so that the space in each ring is out of line with that in the following ring, as also shown in Fig. 31.

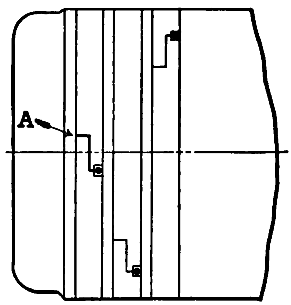


FIG. 31.

THE PISTON is made in one piece, the rings being sprung on over the junk-rings. It should be remembered that with oil engines greater heat is evolved in the cylinder than in steam engines. Consequently the slightest play is allowed to the piston-rings at the sides, and are, therefore, not made so tight a fit as in steam-engine practice.

THE CONNECTING-ROD BEARINGS at piston end are

scraped in the ordinary way, and should be allowed slight play sideways on the gudgeon-pin. In smaller-sized engines 1-64″ can be allowed, this amount being slightly increased in the larger-sized engines. The crank-pin bearing of the connecting-rod is usually allowed a very slight play sideways also.

THE AIR AND EXHAUST VALVES should not be a very close fit in their guides. If the fit in these guides is made too close when the valve-box becomes heated the consequent expansion may cause the valve-stem to stick in the guides, and leakage of the valve will result.

The valve-seats are by some considered best left sharp, being not more than 1-32″ wide before grinding.

THE WATER-JACKETS of cylinder or valve-boxes should be all tested by hydraulic pressure to at least 120 lbs. pressure per square inch before the piston is put into the cylinder.

THE FLY-WHEELS require careful keying onto crank-shaft. If the keys are not a good fit and not driven home tight the engine may knock when running. Two keys in larger-sized engines are usually supplied, one being a sunk key, which is fitted to keyway in recessed shaft as well as to the keyway cut in the fly-wheel hub, the second key being only recessed in the fly-wheel and being concave on the lower side to fit the shaft.

OIL-SUPPLY PIPES which have to withstand pressure should have the fittings "sweated" on, the unions being screwed into place on the brass or copper pipe while the solder is still in a liquid state.

CYLINDERS made of two or more parts require the joints of internal sleeve to be made with great care.

Asbestos or a copper ring is used to make this joint; sometimes wire gauze with asbestos is used, which has been found to give very good results.

CYLINDER LUBRICATORS.—The lubrication of the piston in explosive engines is of great importance. On those engines where it is convenient to use it, a mechanical type of lubricator is added. This device consists of an oil reservoir into which a wire attached to a revolving spindle is periodically dipped, the wire being also arranged to wipe over a projection which conducts the oil to a receptacle placed above the reservoir and connected to the top of the cylinder. The revolving spindle is driven by belt from the cam-shaft. This lubricator is advantageous because the oil must be always fed to the piston while the engine is working, and the lubricator cannot be left unopened by the attendant, and also because all grit or dirt in the oil is precipitated to the bottom of the reservoir and cannot flow to the piston. Sight-feed lubricators are also now used for the lubrication of the piston, and have proved quite as satisfactory as the mechanical oiler. Such apparatus as well as other lubricating devices are made by the Powell Co.

[Tables giving the Calorific Values of Oils, etc., will be found at end of book.]

CHAPTER III.

TESTING ENGINES.

THE chief object in testing explosive engines at the factory is to ascertain that, in actual working at different loads, the several adjustments are correct. In the steam engine a physical process is completed, requiring only the inlet, expansion, and the outlet of the steam to and from the cylinder, whereas in the oil engine a chemical process is gone through consisting of the introduction of the proper mixture of vaporized oil and air into the cylinder, the ignition of this explosive mixture and the consequent combustion. All this must be accomplished before the piston receives an impulse. In order, therefore, that the best results be obtained, the different mechanisms controlling these processes are each set, and record of their performance during the test is taken with the indicator, which results are again verified by some form of brake attached to the fly-wheels or pulley of the engine, and are further checked in an oil engine by the record of the amount of oil which is consumed for the power developed. Where more detailed tests are required, the temperature of the exhaust gases, the amount of air consumed in the cylinder, its temperature and barometrical pres-

sure, together with the amount of cooling water necessary to keep the cylinder to the required temperature, are each noted and recorded. When the test is made with a new engine, it should be first started up and run without anv load for a short time. The cams are set as

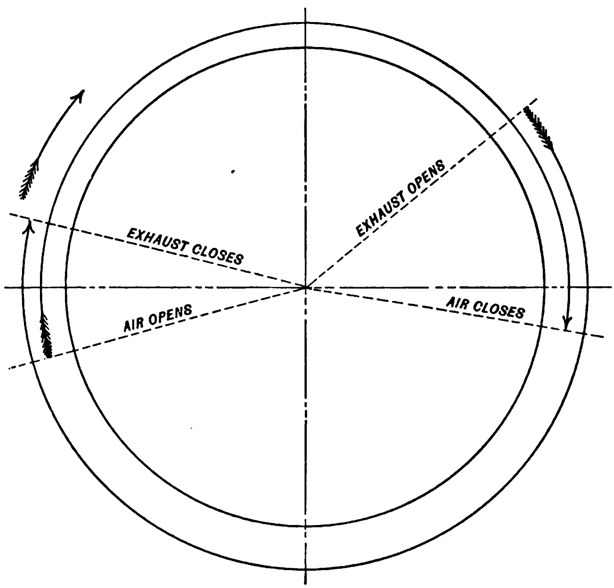


FIG. 32.

shown in diagram, Fig. 32, for engines having both air and exhaust valves actuated from the crank-shaft. The air-valve closes, as shown, just after the crank-pin has passed the out centre, the exhaust-valve opening at about 85 per cent. of the full stroke and closing just

after the air-valve has opened. Where the air-inlet valve is automatic the exhaust-cam only is set, as shown in the diagram, and the air-valve spring should be adjusted so that the incoming air is not choked in passing the valve during the suction stroke.

The oil-pipes leading to the vaporizer or sprayer should be well washed before starting the engine, as with a new engine grit and filings may get into the pipes, and when the engine is started the oil-valves and valve-seats may be damaged. The oil-filter also must be in proper shape and clean, so that the oil can flow freely to the oil-pipe.

After the vaporizer and igniter has been well heated a little oil should be allowed to enter the vaporizer or combustion chamber; then the fly-wheels can be turned forward a few times, after which the engine should start freely. The method of starting the different types of engines is explained in detail in Chapter VII. An engine is sometimes found difficult to start the first time owing to some defect in the castings or workmanship, and if it fails to start, the engine should be examined in detail to ascertain the cause.

First test the oil-inlet or spraying device by hand; then test the pressure of compression in the cylinder by turning the fly-wheels backward. The relief-cam being out of action, it should not be possible with full compression to turn the fly-wheel past the back centre. If the compression is so slight that the pressure in the cylinder can be overcome and the fly-wheel turned during the compression period by hand, then either the piston-rings are leaking or there is leakage past

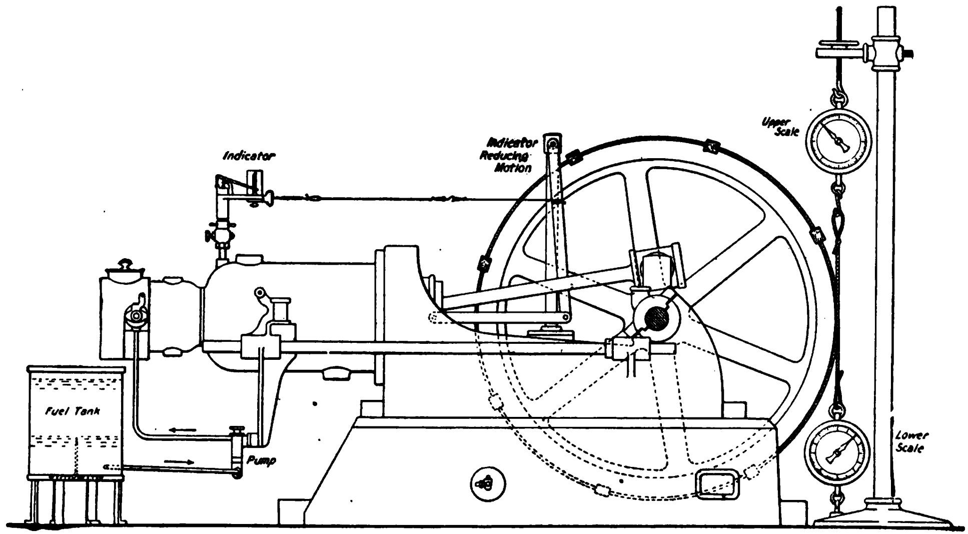

Indicator
Indicator Reducing Motion
Upper Scale
Lower Scale
Fuel Tank
Pump

FIG. 33.

the air and exhaust valves or through some of the joints or gaskets. Air and exhaust valves and piston-rings should be examined, and any appearance of leakage remedied by refitting the piston-rings, as already explained in Chapter II., and the valves, if necessary, should be reground in. New engines also fail to start at times by reason of the leakage of water from the cooling jacket into the cylinder owing to faulty gaskets or flaws in the castings. This leakage of water may sometimes be ascertained by failure to obtain an explosion in the combustion chamber when all conditions in the cylinder and vaporizer are apparently in good order for the engine to start properly. If leakage of water is suspected but cannot be detected in this way, the water-pressure pump should be attached and the water-jackets tested to a pressure of 120 lbs. The crank-shaft and other bearings require careful oiling at first, and full lubrication should be given to the piston; otherwise it may, perhaps, work dry and cut the cylinder.

After working a few hours, the piston should be withdrawn and examined; any hard places on the sides should be eased either by careful hand filing or otherwise. The junk-rings (or distance-pieces between the rings) should be eased if necessary, so that they do not work hard on the cylinder. The full bearing of the piston should be from about $\frac{1}{2}''$ from rings forward to within $\frac{3}{4}''$ of the front end, as already explained in Chapter II.

The terms "brake," or "developed," or "actual" or "effective" H. P., are synonymous, and are used

to signify the power which an engine is capable of delivering at the fly-wheel or belt-pulley. This power is variously designated, and here we shall use the abbreviation B. H. P. to express it. The indicated H. P. represents the whole power developed by combustion in the cylinder, but it is not considered such a reliable method of measuring the power of explosive engines as that of the dynamometer or brake, because the indicator-card only gives the power developed by one or more explosions, whereas the brake can be applied for any length of time and shows the average performance of the engine for a longer period of time.

Fig. 33 illustrates the engine as arranged for testing in the factory. The fuel tank shown at the left hand is placed there for the purpose of running the oil-consumption test. The fuel pump is connected temporarily to this tank instead of taking its supply of oil from the tank in the base of the engine. The indicator is also shown in place on the top of the cylinder. The device for reducing the stroke of the crank to suitable dimensions for the indicator is also shown in place bolted to the bed-plate of the engine. The brake consists of rope ½″ thick, with wooden guides with balances at each extremity. The upper balance is suspended by adjustable hook suitably arranged for altering the load on the brake.

Various kinds of dynamometer brakes are used for testing; that shown in Fig. 33 is considered by the writer as being satisfactory. The brake should be attached as shown in the illustration, the load being taken as the number of pounds shown on the upper

scale less those shown on the lower scale. Brake or actual H. P. is calculated thus:

$$\text{B. H. P.} = \frac{W \times C \times N}{33{,}000}.$$

W = net load in pounds.
C = circumference of wheel.
N = number of revolutions per minute.

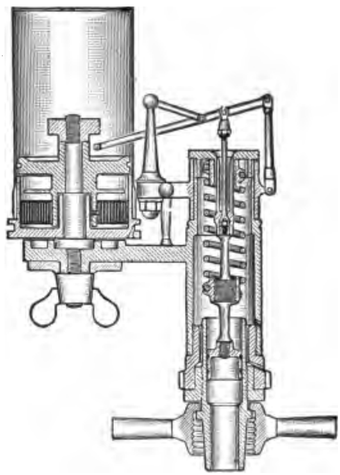


FIG. 34.

The circumference of the wheel should be measured at the centre of the rope, thus allowing for half the rope thickness.

INDICATORS.—Fig. 34 shows the American Thompson Improved Indicator with $\frac{1}{4}''$ area piston.

THE INDICATOR is attached to the cylinder by first screwing into the cylinder the indicator cock, as shown at Fig. 34*a*, to which the indicator is applied in the ordinary way.

The length of the stroke of the engine must be reduced to suit the dimensions of the diagram, which is

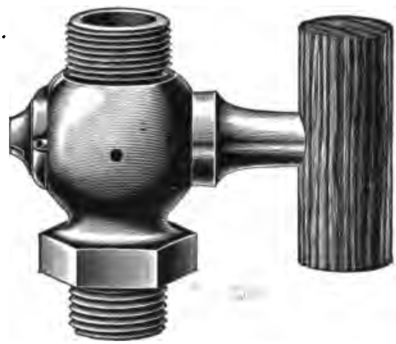


FIG. 34*a*.

usually about 3″ long. This is accomplished by the use of a device, as shown in Fig. 35.

Indicated H. P. is calculated thus:

$$\text{I. H. P.} = \frac{P\,L\,A\,E}{33{,}000}.$$

P = mean effective pressure in lbs.
L = length of stroke in feet.
A = area in inches of piston.
E = number of explosions per minute.

The M. E. P. of indicator-card is obtained by the use of the planimeter, as shown in Fig. 37, or by measuring the card by scale and taking the average pressure.

The illustration (Fig. 36) shows the design and

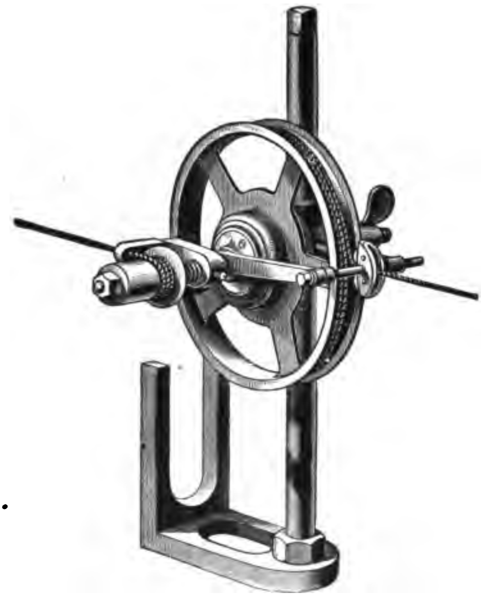


FIG. 35.

arrangement of the parts of the Crosby gas-engine indicator. The cylinder proper is that in which the movement of the piston takes place. The piston is formed from a solid piece of tool steel, and is hardened to prevent any reduction of its area by wearing. Shal-

low channels in its outer surface provide an air packing, and the moisture and oil which they retain act as lubricants, and prevent undue leakage by the piston.

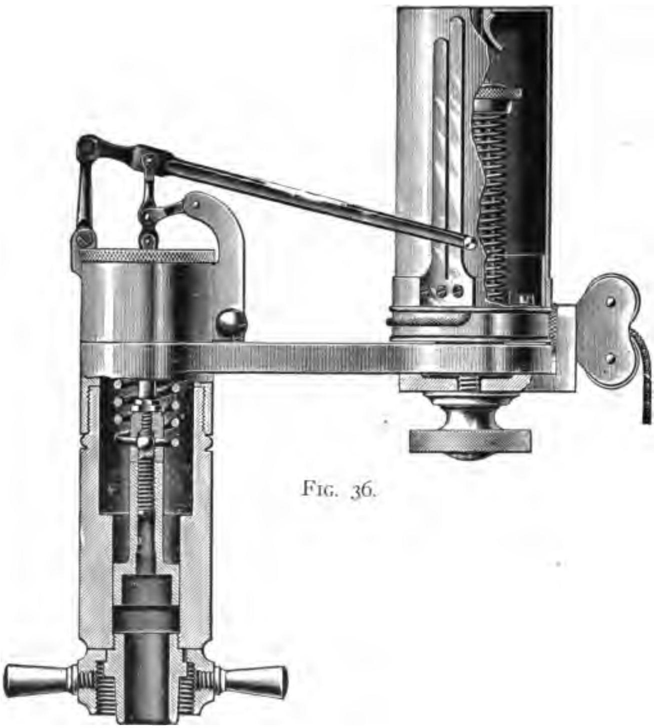


FIG. 36.

The piston is threaded inside to receive the lower end of the piston-rod and has a longitudinal slot which permits the bottom part of the spring with

its bead to drop on to a concave bearing in the upper end of the piston-screw, which is closely threaded into the lower part of the socket; the head of this screw is hexagonal, and may be turned with a hollow wrench.

The swivel-head is threaded on its lower half to screw into the piston-rod more or less according to the required height of the atmospheric line on the diagram. Its head is pivoted to the piston-rod link of the pencil mechanism. The pencil mechanism is designed to eliminate as far as possible the effect of momentum, which is especially troublesome in high-speed work. The movement of the spring throughout its range bears a constant ratio to the force applied, and the amount of this movement is multiplied six times at the pencil point.

Springs.—In order to obtain a correct diagram, the height of the pencil of the indicator must exactly represent in pounds per square inch the pressure on the piston of the oil engine at every point of the stroke; and the velocity of the surface of the drum must bear at every instant a constant ratio to the velocity of the engine piston.

The piston spring is made of a single piece of spring steel wire, wound from the middle into a double coil, the spiral ends of which are screwed into a brass head having four radial wings to hold them securely in place; 80 to 200 lb. spring is a suitable pressure for this work.

This type of indicator is ordinarily made with a drum one and one half inches in diameter, this being

the correct size for high-speed work, and answering equally well for low speeds.

To remove the piston and spring, unscrew the cap; then take hold of the sleeve and lift all the connected parts free from the cylinder. This gives access to all the parts to clean and oil them.

To change the location of the atmospheric line of the diagram.—First, unscrew the cap and lift the sleeve, with its connections, from the cylinder; then turn the piston and connected parts toward the left, and the pencil point will be raised, or to the right and it will be lowered. One complete revolution of the piston will raise or lower the pencil point $\frac{1}{8}''$, and this should be the guide for whatever amount of elevation or depression of the atmospheric line is needed.

To change to a left-hand instrument.—If it is desired to make this change: First, remove the drum, and then with the hollow wrench remove the hexagonal stop screw in the drum base, and screw it into the vacant hole marked *L*; next, *reverse* the position of the adjusting handle in the arm; also, the position of the metallic point in the pencil lever; then replace the drum, and the change from right to left will be completed.

The tension on the drum spring may be increased or diminished according to the speed of the engine on which the instrument is to be used, as follows: Remove the drum by a straight upward pull; then raise the *head* of the spring *above* the *square* part of the spindle, and turn it to the right for more or to the left for less tension, as required; then replace the head on the spindle.

Before attaching the indicator to an engine, allow air to blow freely through pipes and cock to remove any particles of dust or grit that may have lodged in them.

The indicator should be attached close to the cylinder whenever practicable, especially on high-speed engines. If pipes must be used they should not be smaller than half an inch in diameter, and as short and direct as possible.

The indicator can be used in a horizontal position, but it is more convenient to take diagrams when it is in a vertical position, and this can generally be obtained, when attaching to a vertical engine, by using a short pipe with a quarter upward bend.

The motion of the paper drum may be derived from any part of the engine, which has a movement coincident with that of the piston. In general practice and in a large majority of cases the piston itself is chosen as being the most reliable and convenient.

When the indicator is in position and the cord-drum or other reducing motion is correctly placed, it is next necessary to adjust the length of the cord, so that the drum will clear the stops at each extreme of its rotation. The engine should be allowed to run for a few minutes to heat up before taking a diagram. The atmospheric line should be drawn by hand, preferably after the diagram has been taken and when the instrument is heated up; the card is then taken with full-rated load on the brake. It is well to allow the pencil to go several times over the paper so as to procure a card showing several explosions, and thus the average pressure can be taken.

The pressure of the pencil on the paper can be adjusted by screwing the handle in or out, so that when it strikes the stop there will be just enough pressure on the pencil to give a distinct fine line. The line should

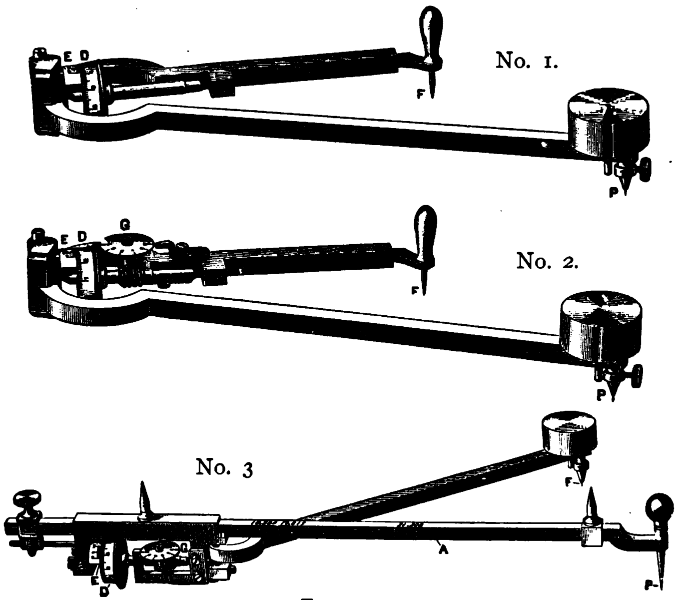


FIG. 37.

not be heavy, as the friction necessary to draw such a line is sufficient to cause errors in the diagram.

THE PLANIMETER or averaging instrument is shown at Fig. 37. No. 1 planimeter is the simplest form of the instrument, having but one wheel, and is designed to measure areas in square inches and decimals of a

square inch. The figures on the roller wheei *D* represent *units,* the graduations *tenths,* and the vernier *E* gives the *hundredths.* *F* is the tracer and *P* is the pivot.

Fig. 37 represents the No. 2 planimeter, which is the same as the No. 1, with the addition of a counting disc *G,* the figures on which represent *tens* and mark complete revolutions of the roller-wheel. By this means areas greater than ten square inches can be measured with facility. The result is given in square inches and decimals, and the reading from the roller wheel and vernier is the same as with No. 1.

Fig. 37 represents the No. 3 planimeter, which differs somewhat in design from the two previously described. It is capable of measuring larger areas, and by means of the adjustable arm *A* giving the results in various denominations of value, such as square decimeters, square feet and square inches; also of giving the average height of an indicator diagram in fortieths of an inch, which makes it a very useful instrument in connection with indicator work.

Directions for Measuring an Indicator Diagram with a No. 1 or No. 2 Planimeter.

Care should be taken to have a flat, even, unglazed surface for the roller wheel to travel upon. A sheet of dull-finished cardboard serves the purpose very well. Set the weight in position on the pivot end of the bar *P,* and after placing the instrument and the diagram

in about the position shown in Fig. 37*a*, press down the needle point so that it will hold its place, set the tracer; then at any given point in the outline of the diagram, as at *F*, adjust the roller wheel to zero. Now follow the outline of the diagram carefully with the tracer

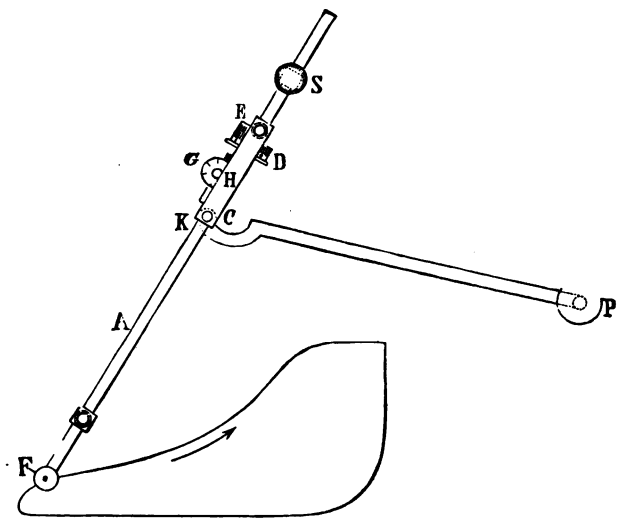


FIG. 37*a*.

point, moving it in the direction indicated by the arrow, or that of the hands of a watch, until it returns to the point of beginning. The result may then be read as follows: Suppose we find that the largest figure on the roller wheel *D* that has passed by zero on the vernier *E* to be 2 (units) and the number of graduations that have also passed zero on the vernier to be 4

(tenths), and the number of graduation on the vernier which exactly coincides with the graduation on the wheel to be 8 (hundredths), then we have 2.48 square inches as the area of the diagram. Divide this by the length of the diagram, which we will call 3 inches, and we have .8266 inch as the average height of the diagram. Multiply this by the scale of the spring used in taking the diagram, which in this case is 40, and we have 33.06 pounds as the mean effective pressure per square inch on the piston of the engine.

Directions for Using the No. 3 Planimeter.

No. 3 planimeter is somewhat differently manipulated, although the same general principle obtains. The figures on the wheels may represent different quantities and values, according to the particular adjustment of the sliding arm *A*. If it is desired merely to find the area in square inches of an indicator diagram, set the sliding arm so that the 10-square-inch mark will exactly coincide with the vertical mark on the inner end of the sleeve *H* at *K*. The sliding arm is released or made fast by means of the set-screw *S*.

With the wheels at zero and the planimeter and diagram in the proper position, trace the outline carefully and read the result from the roller wheel and vernier, the same as directed for the No. 1 and No. 2 instruments.

The indicator-card shows what is occurring inside the cylinder and combustion chamber during the different periods of the revolution. It gives a record of the

variations in pressure, and also the exact points of the opening and closing of the valves. With the Otto or Beau de Rochas cycle the four strokes are as follows: Suction (*A*), compression (*B*), expansion (*C*), exhaust (*D*). The lines in the diagram are correspondingly lettered (see Fig. 38), and they represent each of these processes.

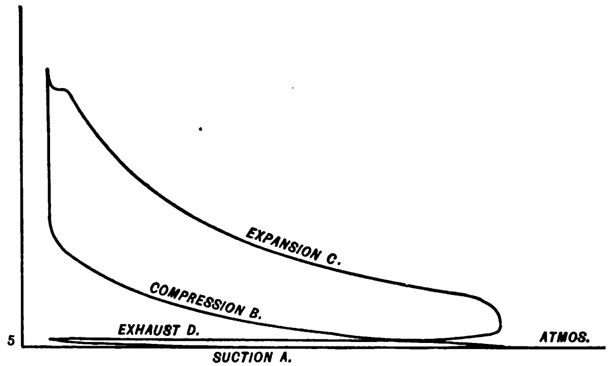


FIG. 38.

Fig. 39 shows a good working diagram, in which the mixture of air and hydrocarbon gas is correct and where combustion is practically complete. The ignition line in this diagram is nearly perpendicular to the atmospheric line, but inclines slightly toward the right hand at top. The diagram also shows the opening of the exhaust-valve at the proper time—namely, at 85 per cent. of the stroke. The compression line represents the proper pressure, and the air-inlet and exhaust lines indicate correct proportioned valves and inlet and outlet passages.

In considering and analyzing diagrams the following hints will perhaps be of service. If the suction line of the diagram is shown below the atmospheric

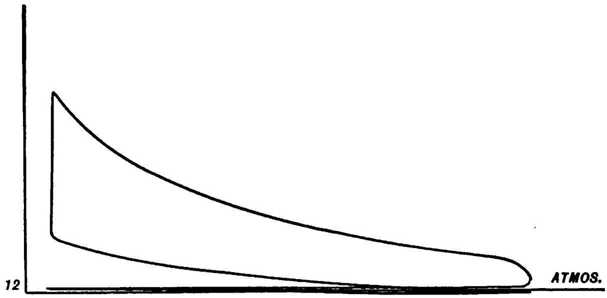


FIG. 39.

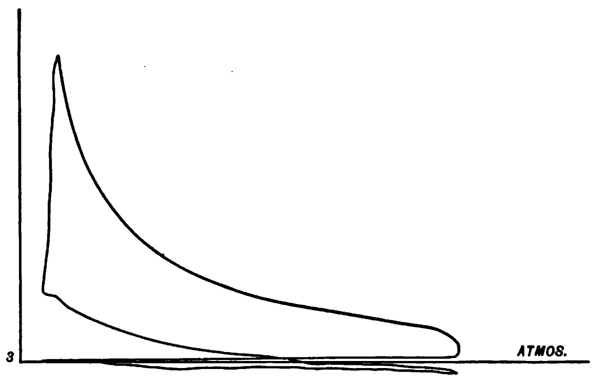


FIG. 40.

line, as in Fig. 40, then the air-inlet to the cylinder is known to be in some way choked. Where the air-valve is automatic this defect may be caused by the valve-

spring being too strong and it accordingly requires weakening; or the area of the air suction-pipe, if this is used, may be too small or this connection may have too many elbows or bends in it, and should be either of increased diameter or the bends should be eliminated. Again, the valve itself may have too small an area, or if actuated have insufficient lift (the proper lift of a valve is $\frac{1}{4}$ of its diameter), or the period of opening of the valve may not be correct, and the setting of the cams should be carefully examined, and, if necessary, altered in accordance with the diagram of valve opening, as shown at Fig. 32.

If the compression line *B* shows insufficient pressure of compression, this indicates leakage, which is probably due either to leaky piston or valves. If this leakage is past the piston-rings, the escaping air may be heard and the lubricating oil will be seen at each explosion period to be splashing and blown past the rings of the piston. If no signs of piston leakage are noticed, then examine oil-inlet air and exhaust valves and valve-seats very carefully; also note the various joints in the valve-box and otherwise where leakage might possibly occur. In engines without water-jackets around the valve-box the heat of the exhaust gases continually passing through the valve-chamber may sometimes cause the valve-seats to expand unequally when heated, and consequent leakage will occur when working.

If leakage is detected at the valves they must be reground, and also any hard places on the valve-stems or guides where they become heated should be eased so that the valves will work easily and efficiently when the

seats and guides are expanded, and, perhaps, slightly distorted, by the heat of working. (It is understood that these remarks refer to new engines solely.) With some engines means of increasing the compression by movable plates on the connecting-rod crank-pin end or other somewhat similar means are provided which can be changed, if necessary, thus decreasing the

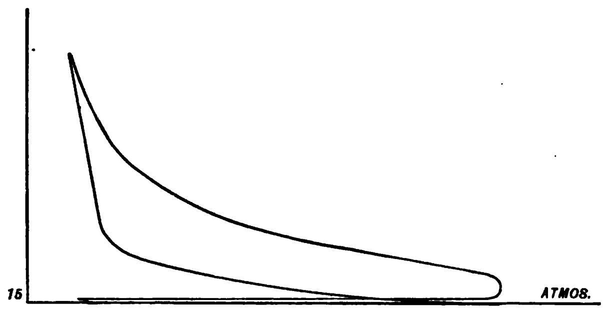


FIG. 41.

amount of clearance in the cylinder. If the piston-rings are without leakage and they have worked into their proper bearings in the cylinder, and if all the valves are in perfect order and without leakage, and still the compression pressure, as shown on the diagram and as already explained, requires increasing, then the clearance in the cylinder can be slightly decreased where it is possible to do so. The vertical ignition line shows the timing of the ignition, and also the initial pressure of explosion. If this line is as represented in Fig. 41 the ignition is known to be too early, and should be arranged to occur somewhat later. The

diagrams as shown in Fig. 42 has the ignition line too late.

The timing of the ignition is regulated as follows:

With electric ignition by altering the period of

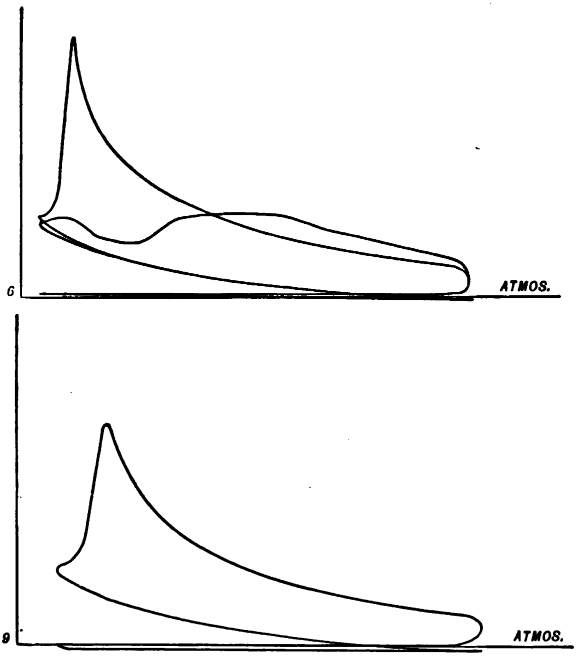


FIG. 42.

sparking. Thus, if later ignition is required the igniting device must not be allowed to spark till the crank-pin has travelled nearer to the dead centre. With the hot-tube ignition and no timing valve, the length of the

tube can be changed. For example, to retard the ignition the tube should be lengthened slightly and its temperature somewhat decreased. In engines where neither of these means of ignition is used, but where the ignition is caused by the heat of the vaporizer-chamber or somewhat similar device, the timing of the ignition is controlled by the heat of the vaporizer-chamber and also by the heat generated by the process of compression. Where the ignition in this case is to be retarded, the compression should be reduced slightly and the vaporizer or other igniting device maintained at a less heat. The ignition, however actually caused, is always influenced by the heat of the cylinder walls and the temperature of the incoming air, which correspondingly increases or decreases the heat caused by the compression before explosion takes place. The ignition is usually adjusted when testing engines with the cooling water issuing from the cylinder water-jackets at a temperature of 110° to 130° Fahr.

The expansion line is marked *C*, as shown in Fig. 38. This line indicates the initial pressure of combustion, and it also shows the developed pressure decreasing as the volume of the cylinder becomes greater with the piston moving forward. The effective pressure developed is measured from this line to the compression line, and varies according to the richness of the explosive mixture. When the engine is in actual use the governor controls this pressure automatically.

The mean effective pressure is greater in some types of engines than it is in others, and varies, as stated in Chapter II., from 40 to 75 lbs. The amount of the

pressure in the cylinder is dependent upon the method of vaporization, upon the proper mixture of the gas

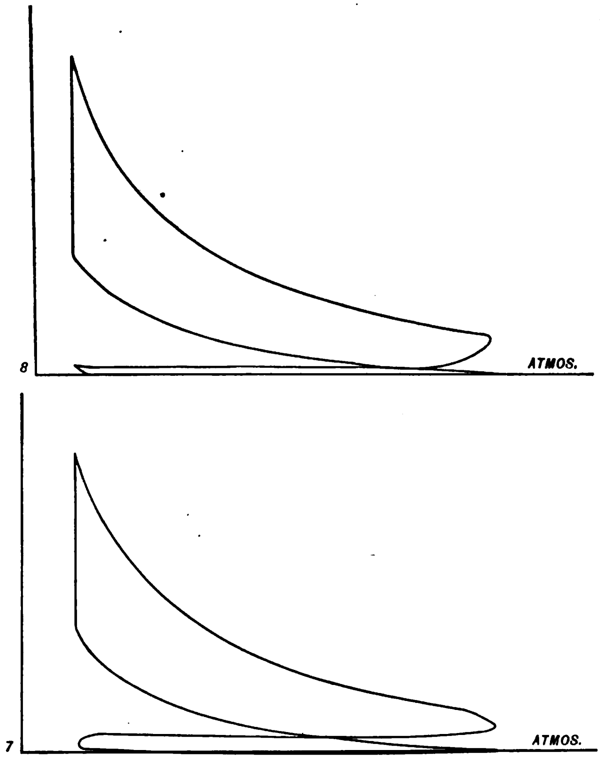


FIG. 43.

and air before explosion, and also upon the pressure of the compression. As in gas engines, the tendency in oil-engine practice is toward higher compression to

increase their efficiency. Where the mean effective pressure is low the relative power of the engine will, of course, also be reduced. The greatest mean effective pressure should be attained when the oil is thoroughly vaporized, is properly mixed with the air and when the compression is as high as practicable without pre-ignition taking place.

Should the exhaust lines *D* appear as in Fig. 43, then it is understood that the discharge of the exhaust gases is in some way choked; this may be caused by the exhaust-valve itself being too small, or to the periods of the opening of the valve being incorrect. (See diagram, Fig. 32.) Again, this defect may be caused by too many sharp bends, too small diameter exhaust-pipe, or possibly too long an exhaust-pipe. Theoretically no back pressure should be allowed during the exhaust period, but usually in practice a slight pressure of about one pound is recorded.

Each pound per square inch of back pressure shown by the exhaust line shows a back pressure in the cylinder, which is negative work to be overcome by the piston, and represents a slight loss of power by the engine.

Care must be taken that the indicator is in proper condition, without any play in the pencil arm, and that the piston is free and well lubricated. Lost motion in the indicator may show peculiarities in the diagram which to an inexperienced manipulator may be the cause of trouble.

TACHOMETERS (Fig. 44).—These instruments have been designed for the purpose of ascertaining at a

glance the number of revolutions made in a given time by rotating shafts. Their construction is based on centrifugal power, and they consist of a case inside of which are mounted a pendulum ring, in connection with a fixed shaft, a sliding rod and an indicating

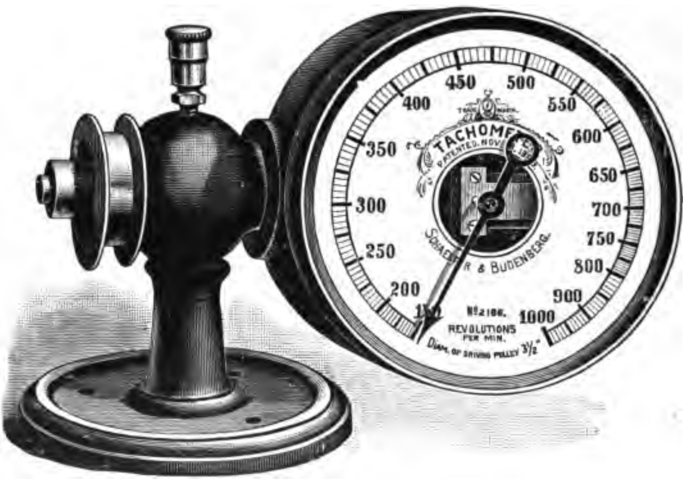


FIG. 44.

movement. The apparatus is very sensitive, and will indicate the slightest deviation in speed.

PORTABLE TACHOMETER (Fig. 44*a*).—This instrument is similar in construction to the tachometer for permanent attachment. By applying it by hand to the centre of rotating shafts, it will instantly and correctly indicate the number of revolutions of the shaft per minute.

Fig. 44*b* illustrates a new form of speed counter, the

invention of Mr. A. J. Hill, of Detroit, Mich., which, besides counting, also registers the number of revolu-

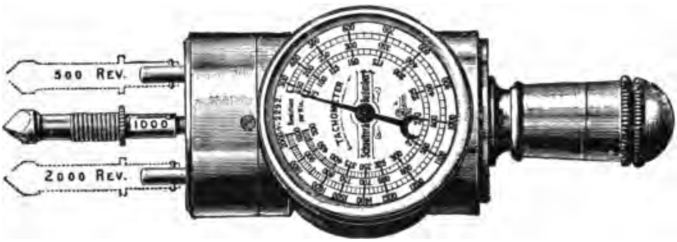
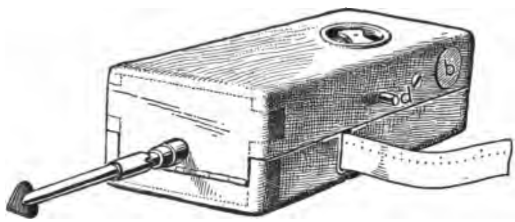


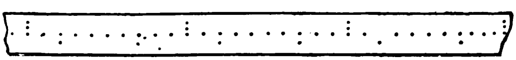
FIG. 44*a*.

tions of the shaft. This is accomplished by simply punching a continuous slip of paper, as shown in



44*b*.

Fig. 44*c*. The watch mechanism in the device also periodically records a detent in the paper slip, thus



44*c*.

marking the periods of time while the shaft actuates the mechanism of the device, causing a detent for each

revolution. The writer has not yet had an opportunity of testing this interesting and useful invention.

When the full brake H. P. is obtained, which should be developed for at least a period of one hour continuously, the consumption fuel test is made.

THE MECHANICAL EFFICIENCY of oil engines, as shown by records of various tests, should be from 80 per cent. to 88 per cent., although the efficiency is much less than this when the engine has been working only a short time and before the crank-shaft and other bearings and piston are worn in. To ascertain the mechanical efficiency of an engine, first calculate the I. H. P., as already described; then figure the B. H. P., as already shown. Then:

$$\text{Mechanical efficiency} = \frac{\text{B. H. P.}}{\text{I. H. P.}}$$

For instance: If the B. H. P. of an engine = 10 and the I. H. P. = 12.5,

$$\text{Mechanical efficiency} = \frac{10}{12.5}$$
$$= 80 \text{ per cent.}$$

THERMAL EFFICIENCY.—The ratio of the heat utilized by the engine, as shown by the power (B. H. P.) developed, as compared with the total heat contained in the fuel absorbed by the engine, is known as the thermal efficiency. This can be obtained by the following formula:

$$\frac{42.63 \times 60}{C \times X}.$$

C = consumption of fuel in pounds per B. H. P. per hour.

X = calorific value of the fuel per pound in heat units.

The thermal efficiency of the oil engine is low as compared with the gas engine. The best gas-engine makers now claim a thermal efficiency for their engines of 27 per cent., whereas it is believed the maximum thermal efficiency recorded by any oil engine now in regular use is 18 per cent.

The following heat table shows the disposition of heat in oil engines as given by Dugeld Clerk:

Heat shown on diagrams per I. H. P. . .	15.3 per cent.
Heat rejected in water-jackets	26.8 per cent.
Heat rejected in exhaust and other losses	57.9 per cent.
	100 per cent.

It may be remarked, however, that this efficiency, though seemingly low, compares well with that of the steam engine, of which the average recorded results show about 11 per cent. thermal efficiency.

Fuel Consumption Test.—This is generally made with all new engines before they leave the factory, and is advantageous as a check of the efficiency of the engine as shown by the indicator and the brake tests, and this test is also useful to ascertain the exact consumption of fuel by the engine in actual operation.

The oil is weighed, the amount being gauged by weight of fuel rather than by measuring the oil. The tank or other receptacle from which the fuel is drawn is first filled with kerosene. The tank is then placed on platform scales, and the weight is carefully taken and time noted when the engine is ready to begin this test. The full load required is then adjusted on the brake while the engine is running at its normal speed.

The oil can also be measured by means of a pointer placed in the tank, the tank being filled until the pointer is just visible before the engine is ready for the test to commence. The oil is then weighed in a separate vessel, and a quantity of the fuel is poured into the test tank. When the test is completed, the oil is taken out of the tank until the pointer shows again just as it did at the commencement of the test. The weight of the kerosene remaining in the vessel is deducted from the whole weight as at first recorded, and the difference is the amount consumed by the engine. It is usual to continue this test for at least one hour's duration. During the consumption test, the load on the brake and the number of revolutions per minute are recorded and the average brake horse-power developed is taken. The exact amount of oil consumed per hour being also known, the consumption of oil per H. P. hour is simply ascertained.

Light spring indicator diagrams are taken to ascertain the efficiency of the air and exhaust valves, ports and passages. That shown at Fig. 45 is taken with $\frac{1}{20}$ spring. The indicator must be fitted with special stop arrangement to prevent the pencil going above

the drum of the indicator when taking light spring cards.

It is advantageous to have some method of limiting the supply of oil to the vaporizer arranged so as to prevent the engine from consuming an excess of oil at any time. This gauge should be made immediately after the consumption test has been proved as satisfactory, and to avoid possible mistake by alteration of the oil supply. As already described, if too much oil enters

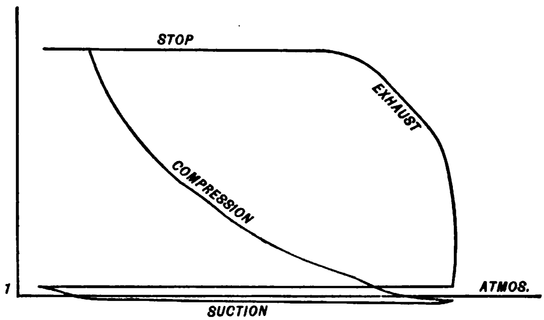


FIG. 45.

the vaporizer, bad combustion will follow and carbonization will, perhaps, result, thus rendering the piston sticky and gummy, and materially reducing the efficiency of the engine.

The exact periods for the movements of the valve and cams should also be clearly marked on the gearing or elsewhere, so that if at any future time the crank-shaft is taken out or the gearing (or other mechanism) between the crank-shaft and the cam-shaft removed,

the relative position of the crank-shaft with the valve mechanism can be readily ascertained and the exact position of the cams again found without difficulty.

EXHAUST GASES.—With an oil engine it is important to note the color of the exhaust gases, which may vary a little according to the weather. Where complete combustion is taking place, the exhaust gases are almost, if not entirely, invisible. When the engine is first started, these gases will, perhaps, be white, gradually getting bluer.

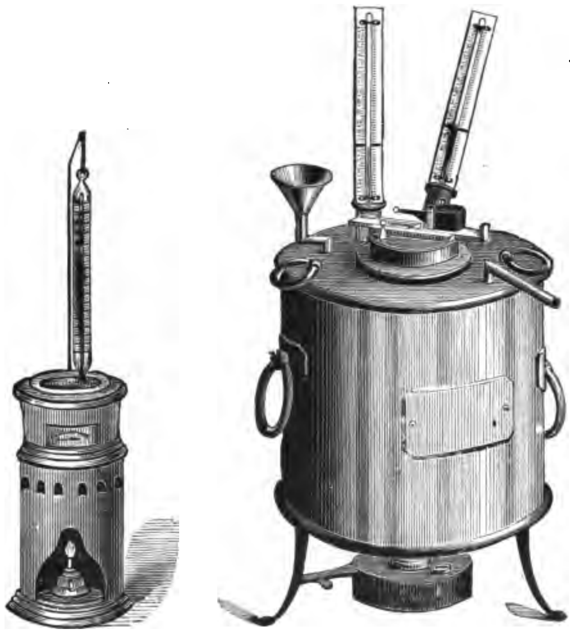
If an oil engine is working well and if the combustion is complete, the exhaust gases will not be seen but only heard, and the piston will also remain clean in working.

TESTING THE FLASH POINT OF KEROSENE.—Fig. 46*a* shows apparatus for ascertaining the "open fire" test or the temperature at which kerosene will flash or explode. This device consists of a small copper vessel in which the kerosene is placed. This vessel is immersed in a larger vessel containing water, which forms part of the upper part of the apparatus.

A thermometer is suspended with its lower part in the oil. A heating lamp placed under the receptacle containing the water raises the temperature of both water and oil as required. A lighted taper is passed to and fro over the top of the oil as it becomes heated. When the vapor given off by the oil flashes the temperature is noted, and that is termed the "flashing point" of the oil thus tested.

The "Abel" oil-tester is shown at Fig. 46*b*. This

was originated by Sir Frederick Abel, and hence its name. The tests made with this apparatus are those known as the " Abel closed" test. Such tests are recognized by the law (at the present time) of Great Britain.



a. *b.*

FIG. 46.

The device consists of a copper vessel containing water in which is an air-chamber. In the air-chamber is placed an oil-cup made of gun-metal. This oil-cup is supplied with tight-fitting lid, and is provided with gas

or oil lamp suitably arranged to ignite the oil vapor when required.

Two thermometers are required, one immersed in the oil and the other in the water, each having a tight joint around it.

The following are the instructions for performing this test: The heating vessel or water-bath is filled until the water flows out at the spout of the vessel. The temperature of the water at the commencement of the test is 130° Fahrenheit. The water having been raised to the proper temperature, the oil to be tested is poured into the petroleum cup, until the level of the liquid just reaches the point of the gauge which is fixed in the cup. If necessary, the samples to be tested should be cooled down to about 60°. The lid of the cup with the slide closed is then put on, and the oil-cup is placed in the water-bath or heating vessel, the thermometer in the lid of the cup being adjusted so as to have its bulb immersed in the liquid. The test-lamp is then placed in position upon the lid of the cup, the lead line, or pendulum, which has been fixed in a convenient position in front of the operator, is set in motion, and the rise of the thermometer in the petroleum cup is watched. When the temperature has reached about 66° the operation of testing is to be commenced, the test flame being applied at once for every rise of 1° in the following manner:

The slide is slowly drawn open while the pendulum performs three oscillations, and is closed during the fourth oscillation. Thus a flame is made to come in contact with the vapor above the oil. The temperature

at which the vapor flashes is noted, and is called the flashing point of the oil. If it is desired to employ the test apparatus to determine the flashing points of oils of very low volatility, the mode of proceeding is modified as follows:

The air-chamber which surrounds the cup is filled with cold water, to a depth of 1½ inches, and the heating vessel or water-bath is filled with cold water. The lamp is then placed under the apparatus and kept there during the entire operation. If a very heavy oil is being dealt with, the operation commences with water previously heated to 120° instead of with cold water.

VISCOSITY OF OIL.—It is frequently advantageous to ascertain the viscosity of different oils. The device shown at Fig. 46*c* is manufactured by C. I. Tagliabue especially for this purpose. The viscosity of an oil with this apparatus is found by noticing the number of seconds required for fifty cubic centimetres of oil to pass the open faucet or valve.

To test the viscosity of oil at 212° Fahr. with this apparatus, first pour water into the boiler through opening *A*, unscrew safety-valve until water-gauge shows that the boiler is full, open stop-cock *B*, making a direct connection between the boiler and upper vessel which surrounds the receptacle in which the oil to be tested is placed. Suspend a thermometer so that its bulb will be about ¼ inch from the bottom of the oil-bath. After carefully straining 70 cubic centimetres of the oil to be tested, which must be warmed in the case of very heavy oils, pour same into the oil-bath. Close

stop-cocks *D* and *E*. Screw the extension *F* with rubber hose attached into the coupling *G*, and let the open end of the hose be immersed in a vessel of water,

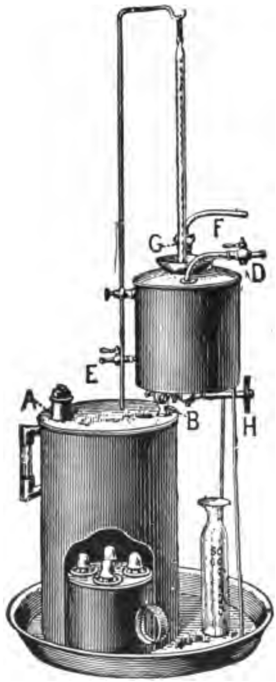


FIG. 46*c*.

which will prevent too large a loss of steam. Place lamp or Bunsen burner under boiler; screw steel nipple marked 212° on to stop-cock *H*; the apparatus is then ready to use. After steam is generated, wait until the

thermometer in oil-bath shows a temperature of from 209° to 211°; then place the 50 cubic centimetre glass under stop-cock *H*, so that the stream of oil strikes the side of test-glass, thereby preventing the forming of air-bubbles; and when the thermometer indicates its highest point open the faucet *H* simultaneously with the starting of the timing watch. When the running oil reaches the 50 cubic centimetre mark in the neck of the test-glass the watch is instantly stopped and the number of seconds noted.

To ascertain the viscosity, multiply the number of seconds by two, and the result will be the viscosity of the oil. For example: If 50 cubic centimetres of oil runs through in 101½ seconds, the viscosity will then be 203.

To test the viscosity of oils at 70° Fahr. screw the steel nipple marked 70 on to faucet *H*; close stop-cock *B*, closing communication between boiler and upper vessel; also close stop-cock *E*. Fill upper vessel through opening *G* with water at a temperature as near 70° as possible, also having the oil to be tested at the same temperature; hang the thermometer in position, and after stirring the oil thoroughly, blow through rubber tube at *D* to thoroughly mix the water; should the thermometer show higher or lower than 70° add cold or warm water until the desired temperature is attained. Then proceed as before stated.

[For tables of tests of various oil engines made at Edinburgh, see end of book.]

CHAPTER IV.

COOLING WATER-TANKS, AND OTHER DETAILS.

WATER is always required to keep the cylinders of explosive engines cool, and is necessitated by the great heat evolved in such engines, which heat would, if it were not carried away, prevent the proper working of an engine by too great expansion of the piston and by burning the lubricating oil. Where running water from city main is not available, water-tanks are used. The engine water-jackets are connected to the tanks as shown in Fig. 47. It is important that the water piping rises all the way from the engine to the tanks. The water, when tanks are used, circulates by gravitation—that is, the cold water being slightly heavier than the hot sinks to the bottom of the tank, passes from the tank to the water-jacket, and returns as warm water to the top of the tank to be cooled off and again sink to the bottom of the tank.

The cooling water-tanks must be of not less capacity than 70 gallons of water per brake H. P. of engine. The tanks when installed should preferably be placed in the best location for cold air to circulate around

them, so that the water in the tanks may cool off as quickly as possible.

Where an engine is required to work for more than ten hours per day, the tanks should be of larger capacity than that above stated, or provision should be made

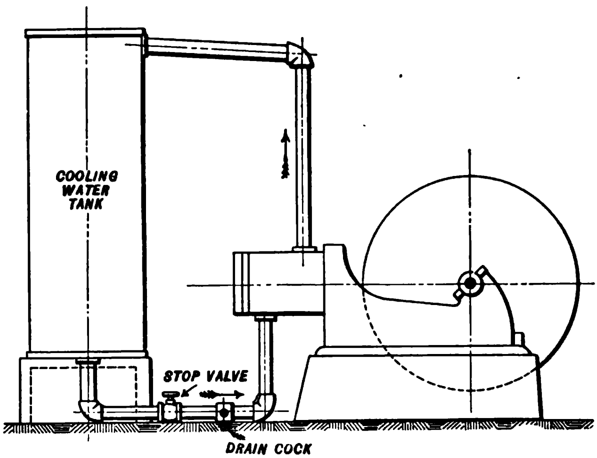


FIG. 47.

to add cold water to the tanks when the water becomes heated above 120° Fahrenheit.

The waste-water drain-pipe from the tanks should be arranged to allow the hot water to run off from the top of the tanks and the cold-water inlet-pipe arranged to enter near the bottom. The circulating-water pipes connecting the tanks to engine water-jacket should be large enough to allow the water to circulate freely. A pipe having $1\frac{1}{2}''$ inside diameter is considered suit-

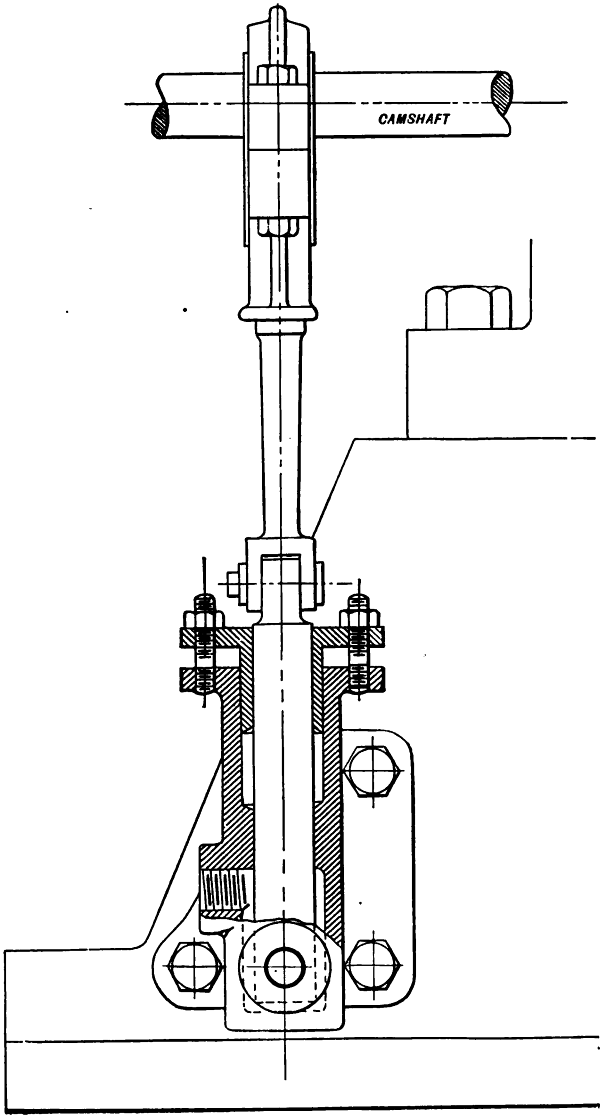


FIG. 48.

able for the smaller size of engines and 3″ diameter pipe is sufficient for engines of 25 B. H. P. and over.

In some installations cooling water is available, but may require pumping to the engine. In such cases a pump capable of delivering more than ten gallons per brake H. P. of engine should be used. This pump can be actuated from the cam-shaft of engine as shown in Fig. 48, or from the crank-shaft by eccentric in the usual way. A rotary pump is sometimes used to accelerate the circulation of water in hot climates with the tank system of cooling water, and can be driven by belting from the crank-shaft of the engine. A by-pass in the water-pipes between the suction-pipe and the discharge-pipe of the water-circulating pump is advantageous, having a regulating valve in the by-pass. If this by-pass is not made, other means should be arranged, so that the supply of cooling water can be regulated to maintain the proper temperature of the cylinder of the engine—namely, 110° to 130° Fahrenheit. This temperature is recommended by the makers of several oil engines.

Where neither pump to lift and circulate cooling water nor water-tanks are necessary and where water is used from the city water-mains, ¾″ inside diameter pipe is sufficient for small and moderate-sized engines. The larger size may have 1″ diameter pipe connections to cylinder.

In all cases, either with tanks, water-pumps, or where the water is connected direct from the city water-main, provision must be made for emptying the cylinder water-jacket and all the water-pipes in time of

frost. If the water in the water-jacket of the cylinder should be allowed to freeze, the cylinder casting may be cracked, and this may necessitate very expensive repairs.

Salt water can be used for cooling the cylinder. It should, however, be pumped through rapidly, so as not to allow the formation of any deposit inside water-jackets. In southern climates or where the temperature of the water is above 70° Fahrenheit, more water is required than above stated to keep the cylinder (when working at full load) below 130°.

The writer has tested such installations requiring 30 gallons per B. H. P. per hour, the normal temperature of the inlet cooling water in this case being 85° to 90° Fahrenheit.

EXHAUST SILENCERS.—The noise from the exhaust gases is sometimes considered to be a great objection to the use of explosive engines, but this is chiefly due to the fact that the ordinary cast-iron exhaust silencing chamber supplied with engine is not designed to entirely silence the exhaust, but is only regarded as sufficient to partly reduce this noise.

Where it is essential that the exhaust be entirely silenced, this can be easily accomplished in the following way: A brick pit should be built as shown in Fig. 49. The exhaust-pipe from the engine is then connected to the bottom of this pit. The outlet-pipe to the atmosphere is connected to the top of the pit. The space inside the pit should be filled with large stones, as shown in illustration. These stones should be about six inches in size, so that crevices are left

between them through which the gases can penetrate. A drain-pipe should be arranged to allow the water to flow out of the pit. The stone or cast-iron plate covering the pit is securely fastened down to the masonry.*

With oil-engine exhaust gases there may be some odor. When it is necessary that both the noise and the

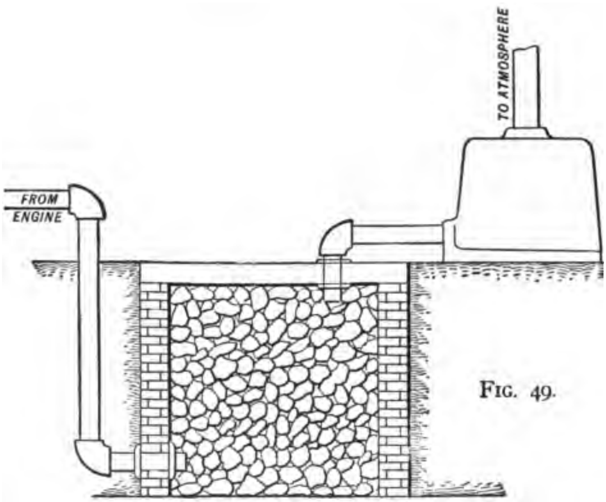


FIG. 49.

odor should be done away with, an exhaust washer should be installed instead of the silencing pit, as already described. This apparatus consists of a tank, to which the water is connected as it issues from the water-jacket of the engine-cylinder, or where cooling

*In some cases the connection is made direct from the engine to the silencer, and thence to the pit, the exhaust pipe leading to the atmosphere being supported from the covering over the pit.

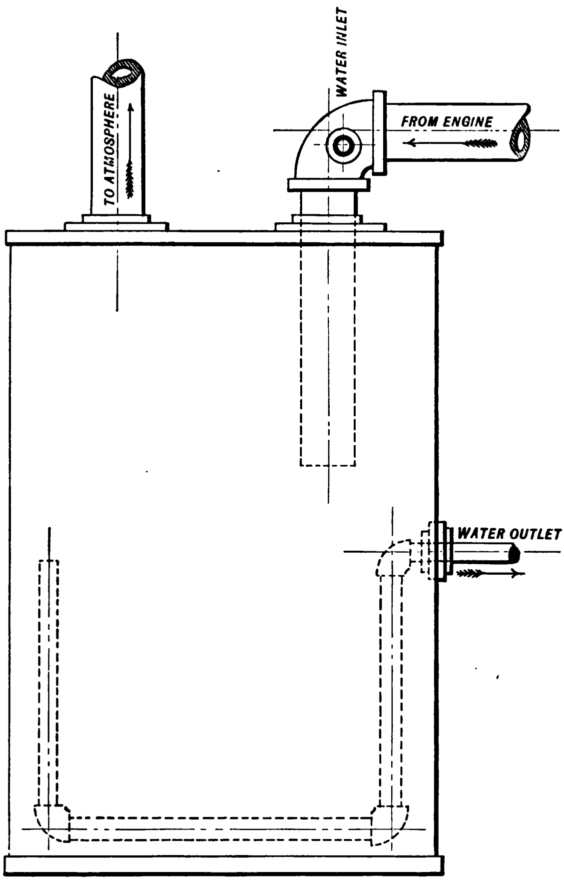


FIG. 50.

tanks are used the water should be taken from the main. About 100 gallons of water are required per hour. The exhaust-pipe from the engine valve-box is also connected directly to this tank. The outlet of the water is connected from the tank to sewer and the outlet exhaust-pipe is also connected in the usual way to the top of the building.

The exhaust gases by this arrangement come in contact with the water and are partly condensed and quite purified. The pressure and noise are eliminated entirely, any deposit of carbon left in the gases after combustion is carried off by the water to the sewer, and there is practically no odor when the gases escape from the exhaust-pipe to the atmosphere at the roof. This device is shown in Fig. 50. The sizes given for piping and tank are those suitable for a 10 to 20 H. P. oil engine. The internal piping in the tank is so placed to avoid any pressure which is created inside the tank due to the exhaust gases of the engine from entering the sewer. If any water is blown out at the top of the exhaust-pipe, a steam exhaust-head is used for obviating this. This apparatus is the same as used on steam exhaust-pipes.

Sizes for piping and tank for a 10 to 20 H. P. oil engine:

Pipe from engine, 3″ diameter.
Pipe of water inlet, ¾″ diameter.
Pipe to atmosphere, 3″ diameter.
Pipe to water outlet, 2″ diameter.
Size of tank, 2′ in diameter by 4′ high.

When it is required to partly silence the noise of exhaust only part or all of the water from the cooling jacket can be turned into the exhaust-pipe directly from the water-jacket. The water is allowed to run to waste again at the silencer. (See Fig. 51.) Wherever water is connected to the exhaust-pipe, care must be taken that none can under any condition enter through

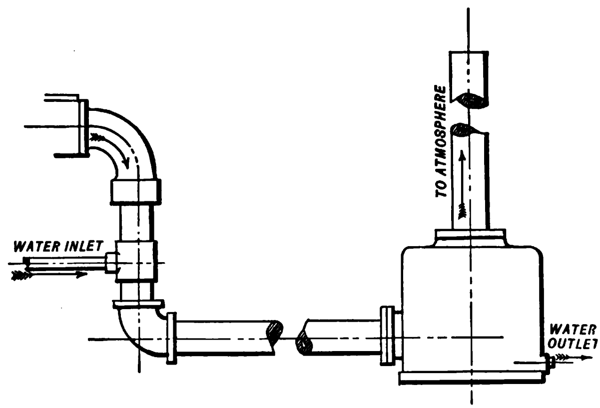


FIG. 51

the exhaust valve-box into the cylinder or vaporizer of the engine. Where water enters the silencer or the piping under pressure from the city main or otherwise, it is necessary that the area of the outlet-pipe be large enough to allow the water to drain freely at atmospheric pressure. If the water is not allowed free drainage, it may quickly fill up the silencer, and perhaps enter the valve-box of the engine, causing the engine to stop working.

SELF-STARTERS.—Engines of 25 H. P. and over should be provided with separate means of starting besides the relief-cam for reducing the pressure of compression as usually provided with the smaller sizes of engines. The weight of the fly-wheels and reciprocating parts on the larger engines which are to be put in motion when being started necessarily entails considerable exertion, and the strength of two men is required to do this work where no other means is provided for this purpose.

There are several different self-starting devices made for gas engines, and it is much easier to accomplish this work with a gas than with an oil engine, since with the former gas only has to be dealt with and can be readily diluted with air and an explosive mixture formed, whereas with the oil engine the fuel must be vaporized first and then mixed with the air before an explosive mixture is available to be ignited and the impulse on the piston obtained. In order, therefore, to accomplish these various operations necessary in the oil engine, sufficient power must be independently provided to turn the engine crank-shaft over two or three revolutions so that the different mechanisms can work, the fuel be injected or inducted into the cylinder or vaporizer, become mixed with the incoming air and an explosion obtained, thus giving the required impulse. This power is usually derived from a separate air reservoir charged during the previous running of the engine or from a small air-compressor operated by hand.

The self-starter used with the Hornsby-Akroyd type

of oil engine is shown in Fig. 52. The reservoir is connected to air and exhaust valve-box of engine through a supplementary valve-box containing two check-valves. These check-valves are arranged to be lifted from their seats by means of the hand-lever as shown.

The following are the instructions in detail for starting these engines by means of this device. (These re-

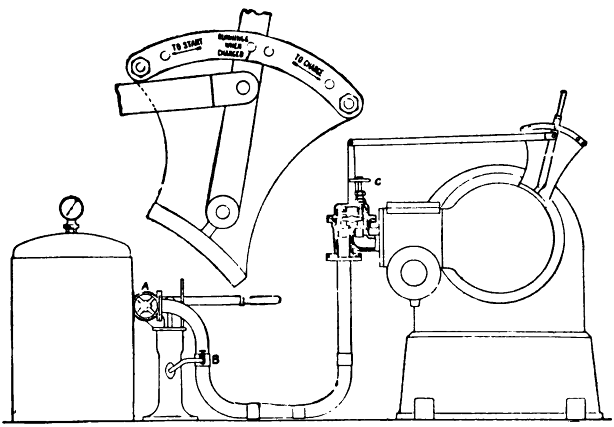


FIG. 52.

marks are generally applicable to all types of engines provided with starting devices of this principle.)

See that the valve *A* on the steel receiver is open, and also the cock *B* on the pipe leading from the hand air-pump. Put the starting lever in the quadrant at the position marked "Running and when charged," and pin it there. Then screw down the valve *C* on the double valve-box, and pump air into the receiver by the

air-pump up to a pressure of say 60 or 70 lbs. to the square inch as shown on the gauge. Then close the cock *B* on the air-pump pipe, withdraw the pin in the starting lever, and put it in the hole by the side of the lever to act as a stop; then place the engine ready for starting as elsewhere described. Place the crank a little over the dead centre in whichever direction the engine is intended to run, unscrew the valve *C* in double valve-box, and then suddenly push the starting lever forward to the end of the quadrant, and the engine will start. Pull the lever back immediately against the pin, and screw down the valves on the double valve-box and on the receiver. Before stopping the engine at any time, pull the lever back and pin it in hole marked "To charge;" unscrew the valves on the double valve-box and receiver, and allow the engine to pump air into the receiver again to 80 or 100 lbs. pressure; put the lever to the centre hole marked "When running, and when charged," and pin it there; screw down the valves on the receiver and valve-box, and the air pressure in the receiver will be retained in readiness to start the engine the next time it is required. If an air-pump is not provided, the engine must be started in the usual way the first time, by pulling round the fly-wheel, and the receiver afterward filled each time before stopping.

UTILIZATION OF WASTE HEAT.—It is frequently advantageous to utilize the heat of exhaust gases and also the heat taken up by the cooling water as it issues from the cylinder water-jacket to heat the rooms of a building or workshop. Sixty per cent. at least of the total

heat evolved from the fuel used in the engine is lost in the exhaust gases and to the cooling water around the cylinder-jacket. This represents a great waste, which can be partly saved in any installations where heat is required for outside purposes.

In instances where this heat can be utilized, the water-pipes should be connected to the cylinder water-jacket outlet and inlet, and arranged to be carried to

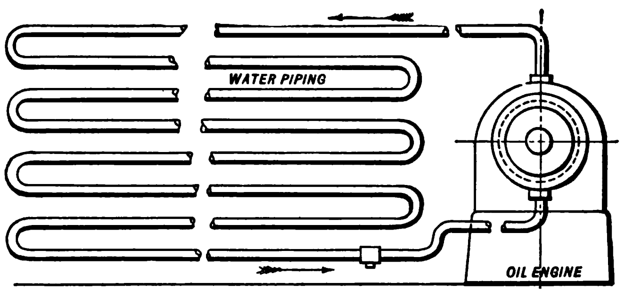


FIG. 53.

supply heat to the building, as shown in Fig. 53. The hot water issues from the cylinder at not less than 110° Fahrenheit temperature, and will heat the piping as shown. With a 10 to 20 brake H. P. oil engine, 200 feet of 2-inch piping can be suitably warmed.

The heat from the exhaust gases can be similarly utilized, the exhaust-pipe being connected and carried along inside the building. In this case the standard size of piping should be slightly increased to avoid choking of exhaust gases, and care should be taken that the piping is not placed within 12 inches of timber.

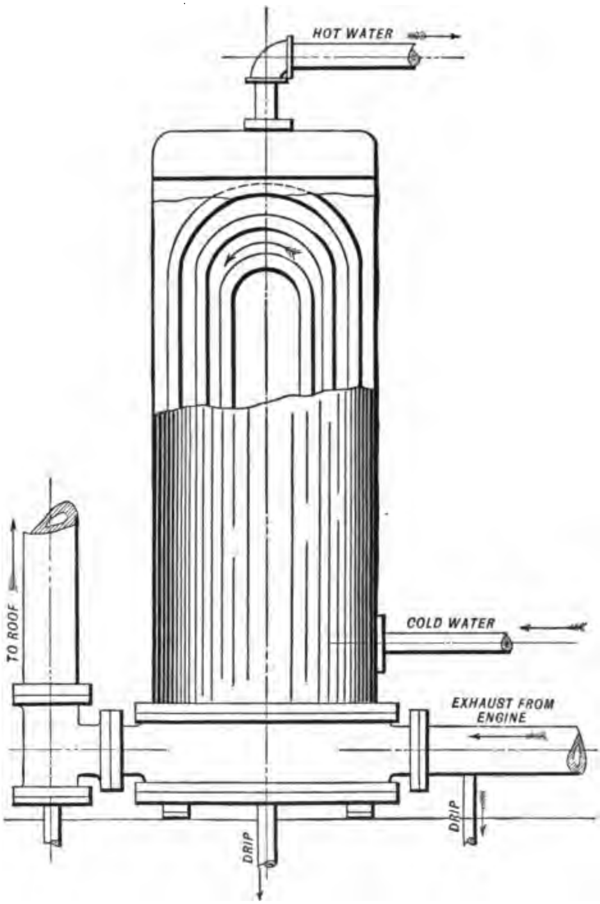


FIG. 54.

The heat in the exhaust gases can also be extracted by the exhaust-pipes being passed through the device, as shown in Fig. 54. Here the water is heated to nearly boiling-point, and will maintain a considerable length of piping at the required heat. With an engine of 15 brake H. P. 200 feet of piping can thus be heated. The heat obtained in these instances is assumed with the engine working at full load or nearly so.

Fig. 54. This apparatus consists of an ordinary feed-water heater, with a number of "U"-shaped internal tubes, through which the exhaust gases pass. The cold water flows in at the lower connection and circulates around the heated tubes, flowing out at the connection on the top of the apparatus, and passes in the piping around the building to be heated in the usual way, and returns by gravitation again to the lower connection.

EXHAUST TEMPERATURE.—The temperature of the exhaust gases is difficult to ascertain correctly. The temperature of the exhaust from the Diesel engine is recorded by Professor Denton as being approximately 740° Fahr. The temperature of different oil-engine exhaust gases varies, and it is probably considerably above that figure. This temperature varies also, of course, according to the size of the engine, and also according to the power that the engine is developing. The heat is greatest at full load and on the largest engines.

CHAPTER V.

OIL ENGINES DRIVING DYNAMOS.

OIL ENGINES for many reasons are well adapted for driving dynamos generating electric current in isolated lighting plants. A large number of such installations have been made in recent years. The oil engine is self-contained, and, unlike a gas engine, is independent of gas works or gas-producer plant for its supply of fuel. Small power installations with oil engines as prime movers should require also less attention than a plant equipped with steam engine and boilers. There is probably not the danger there is with a steam engine of explosion, and as the fuel used is ordinary kerosene of a safe flashing point, there can be little or no fear of destruction by fire. Practically, no hauling of fuel is required, nor is there, with an oil engine, any consumption of water if storage tanks are installed. Further, an oil engine does not deteriorate if only required for part of the year and left standing idle for the remainder of the time. With these and, perhaps, other advantages possessed by oil engines, their adaptability for driving dynamos in isolated electric-lighting and power plants may be understood. Fig. 55 illustrates an oil

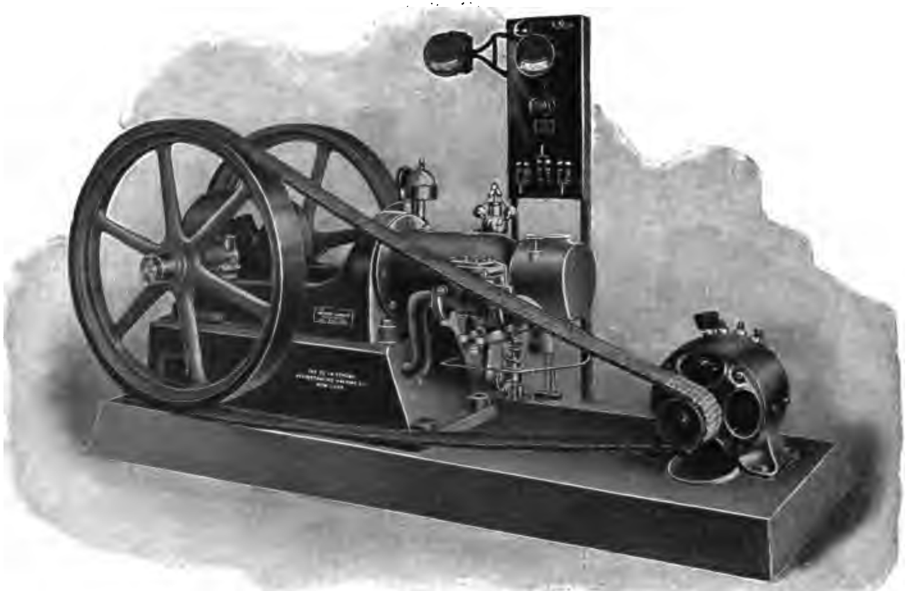


FIG. 55.

engine driving dynamo with link belt. The dynamo is placed close to the engine to economize floor space.

This plant is arranged with the cams having been set for the engine to run backwards.

INSTALLATION.—In order that the plant may be entirely satisfactory and give the best results, it is very essential that the engine and dynamo be correctly located with regard to each other and properly installed at the outset.

THE FOUNDATIONS both for the engine and for the dynamo should be built of good cement concrete, and should be placed on solid ground, so that they are steady and without vibration. The engine foundation can be made as shown at Fig. 56. When, however, the ground that the foundation is built upon is not solid, it is preferred to build the foundation more tapered than shown toward the bottom, thus increasing the surface that the concrete rests on. The weight of the foundation is considered sufficient allowing about 5 cubic feet per I. H. P. for engines under 50 H. P. for concrete. For engines over 50 I. H. P. the foundation can be reduced per I. H. P. If the foundation is built of brickwork, its dimensions should be somewhat greater than those given for concrete. The ingredients of the best concrete are broken stone, Portland cement and sharp sand. The following proportions form a good mixture:

Portland cement	1
Sand	3
Broken stone	4

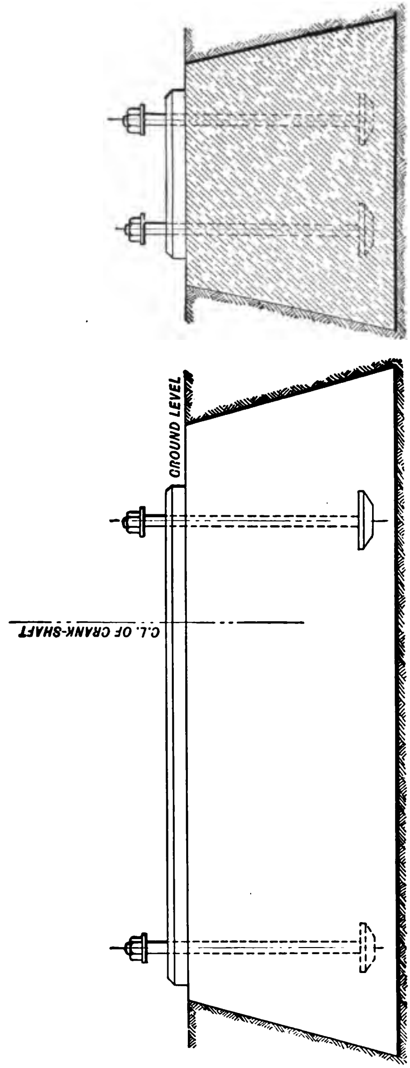


Fig. 56.

When driving by belt the distance between the centres of the dynamo and the engine-shafts is an important feature. Where space is restricted and it becomes essential that the dynamo be placed as close as possible to the engine, it is advantageous to use a link leather belt, allowed to run quite loose, the part of the belt in tension being underneath, the loose part being on top, so that the arc of contact made on the smaller pulley of the dynamo is as great as possible. This arrangement with loose belt lessens the friction on the bearings, which would be occasioned if the belt were made tight, as required at short centres with ordinary leather belt. When using link leather belt, the distance between the centres should be with the usual standard size of fly-wheels 2 to 2.5 diameters of the engine fly-wheels—that is, the distance should not be less than 7 ft. for wheels of 3′ 6″ diameter and not greater than 15 ft. for wheels of 6 ft. diameter. Where ordinary leather belt is used instead of link belt, this distance should be increased to 3 diameters of fly-wheel, but in any case this dimension should not exceed 18 ft. for driving wheels 6 ft. in diameter. To obtain absolutely steady light, it is sometimes advantageous to place a balance-wheel on the armature shaft of the dynamo. This wheel if used should weigh about 15 lbs. per K. W. of dynamo, and be of such diameter that at the maximum speed of dynamo its peripheral speed will not exceed 6000 ft. per minute. This wheel must be accurately balanced, and is usually cast in one piece with pulley, as shown in Fig. 57. The

necessary width of belt to transmit the H. P. may be calculated as follows:

$$\text{H. P.} = \frac{V \times w}{800}.$$

H. P. = the actual horse-power.
V = velocity of belt in feet per minute.
w = width of belt in inches.

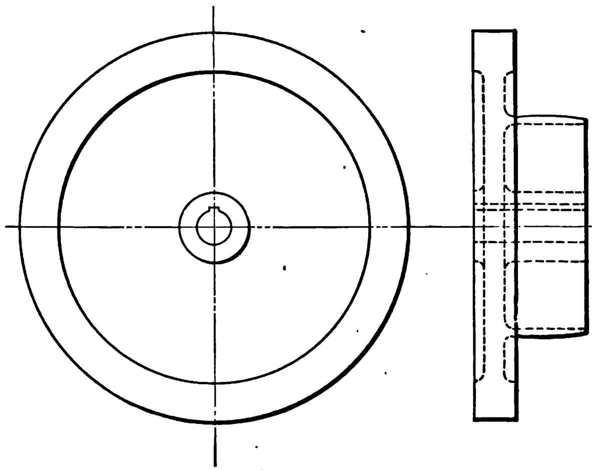


FIG. 57.

The maximum number of incandescent lights available from the dynamo per brake or actual H. P. of engine varies according to the efficiency of the dynamo, and the efficiency of the means of transmission as well as to the efficiency of the electrical installation. Lack of

power as recorded by the electrical instruments is not necessarily due only to defects of the engine, as leakage of power may occur in various ways, as above stated. Usually ten 16 candle-power lights per Brake H. P. are calculated as being a fair load for the engine. With arc lamps of 2000 candle-power, the B. H. P. of engine for each lamp required is approximately .75. It is advisable to have spare power with an explosive engine above that required to run all the lights. Losses of power should be allowed for in the belt, which vary from 10 to 15 per cent.

The regulation of explosive engines for electric lighting must necessarily be such that there is no flicker in the incandescent lights. A speed variation of 2 per cent. is now guaranteed with several oil engines. This regulation gives a very good light and equals that developed with many steam engines.

When space is not available to permit the use of belt transmission, the dynamo is connected directly on to the shaft of the engine, as in Figs. 58 and 58*a*. The coupling between engine-shaft and dynamo is usually flexible to allow of dynamo bearings and the engine-shaft bearings remaining in alignment when they become worn. In direct-connected plants the loss due to the belt transmission is avoided, and a saving is thus effected; but, on the other hand, the first cost of the dynamo is very much greater, running, as it does, at a slower speed than the belt-driven machine, and therefore is of larger dimensions, and consequently more costly.

Fig. 58 illustrates a Hornsby-Akroyd engine of the

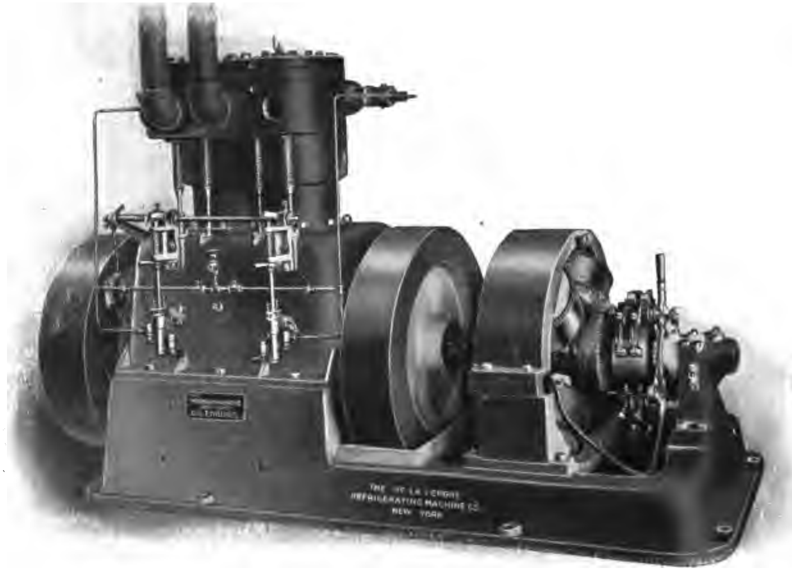


FIG. 58.

two-cylinder vertical type, coupled direct to the shaft of the dynamo, all placed on one bed-plate.

The cranks of the engine are placed in line, and accordingly an impulse at each revolution of the crank-shaft is obtained. The method of working and the details of the vertical type of these engines are very similar to those of the horizontal type elsewhere described. This outfit has given very satisfactory results with incandescent lamp service, the variation in speed being less than 2 per cent. with varying loads, and a large number of these outfits are in use.

Fig. 58*a* illustrates the Mietz & Weiss horizontal type of engine directly connected to dynamo through flexible coupling. This engine, being of the two-cycle type, receives an impulse at each revolution of the crank-shaft, and it runs very regularly and at a high rotative speed—namely, 400 revolutions per minute. The method of working of the Mietz & Weiss engine is fully described in Chapter IX.

The fly-wheels of explosive engines intended for driving dynamos are usually made heavier than when the engines are required for other purposes. (See Chapter II.)

Notwithstanding the special design of engines for electric-lighting purposes and apparent correct adjustment of the governing mechanism, the lights may sometimes be seen to flicker. Flickering in the incandescent lights can be easily located by close inspection of the engine and dynamo, and may be due either to the fly-wheels, the governor, the belt, or the dynamo itself. To precisely locate this defect and remedy it,

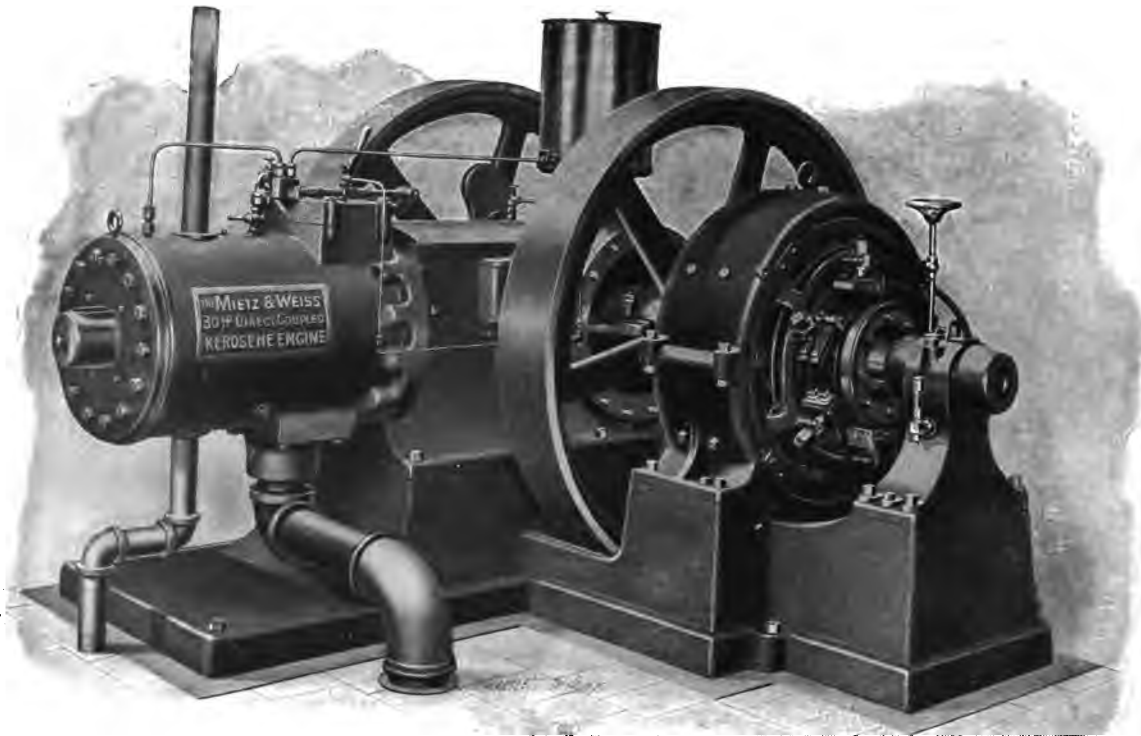


FIG. 58a.

notice the lamps carefully. If the variations in the light are due to want of fly-wheel momentum, such variations will be seen to coincide with the number of revolutions of the engine. Again, if the variation in the lights is only periodical, then this defect should be remedied by adjustment of the governor. Examine carefully the governing mechanism of the engine. If the variation is caused by the governor acting too slowly, then adjust so as to cause more rapid contact with the valve or other controlling mechanism.

The cause of the trouble may not be, as already suggested, in the fly-wheel momentum or in the adjustment of the governor, but in the belt, which is frequently the sole cause of unsatisfactory lighting. The engine and dynamo pulleys over which the belt runs must be exactly in line with each other. The belt should be endless, or if jointed such joints should be very carefully made. A thick, uneven joint in the belt will cause a flicker in the lights each time it passes over the dynamo pulley. The belt should be allowed to run as loose as possible. The writer has seen belts running quite slack and most satisfactorily when the pulleys have been covered with specially prepared pulley-covering material. In some instances in the dynamo itself may be found the cause of the variation in the voltage. If the commutator becomes unevenly worn, or if the brushes are not properly adjusted, unsteady lights will result, and then the commutator should be made of even surface and the brushes correctly adjusted.

Oil engines can be stopped if desired by pressing button in the dwelling-house, an attachment being

added to some engines which automatically turns the stopping handle. This is an advantage where the light is required late at night, and allows the attendant to leave the engine early, at the same time providing requisite illumination as long as required.

AIR SUCTION.—The noise created by the air being drawn into the cylinder has, in some cases, to be silenced. This can be accomplished by connecting the air-inlet pipe to wooden box containing space at least five times as great as the volume of the cylinder—the sides of the box having holes which are lined with rubber. The total area of all these small inlet air holes should be at least three times the area of the air-inlet pipe to the engine.

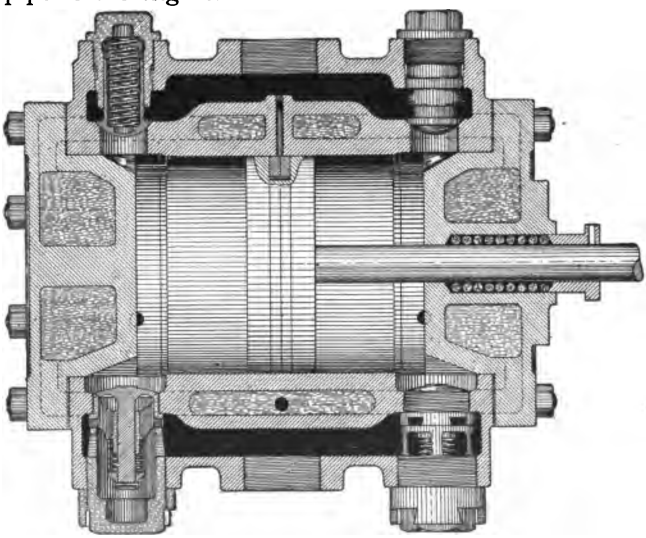


FIG. 59.—Ingersoll-Sergeant air-compressor cylinder (sectional view).

CHAPTER VI.

OIL ENGINES CONNECTED TO AIR-COMPRESSORS, PUMPS, ETC.

THE use of compressed air is now being extensively applied as a means of power transmission, and it is coming more and more into favor in this connection also for actuating pneumatic tools, and for other purposes too numerous to mention. Many advantages are claimed for the combination of explosive engines connected to air-compressors as a motive power.

Fig. 59 shows in section the belted or power-driven air-compressor cylinder as made by the Ingersoll-Sergeant Drill Co. of Easton, Pa. A compressor somewhat similar is shown at Fig. 59*a*, made by the Herron & Bury Mfg. Co., Erie, Pa. The normal speed of these compressors being considerably less than the normal speed of oil engines, they are operated by gearing or by belt from the engine.

Fig. 60 shows an oil engine geared to air-compressor of the ordinary double-acting type. In this outfit the power necessary to actuate the compressor is transmitted by gearing from the engine crank-shaft to the compressor-shaft, which then revolves at a slower speed than the engine-shaft. This arrangement is con-

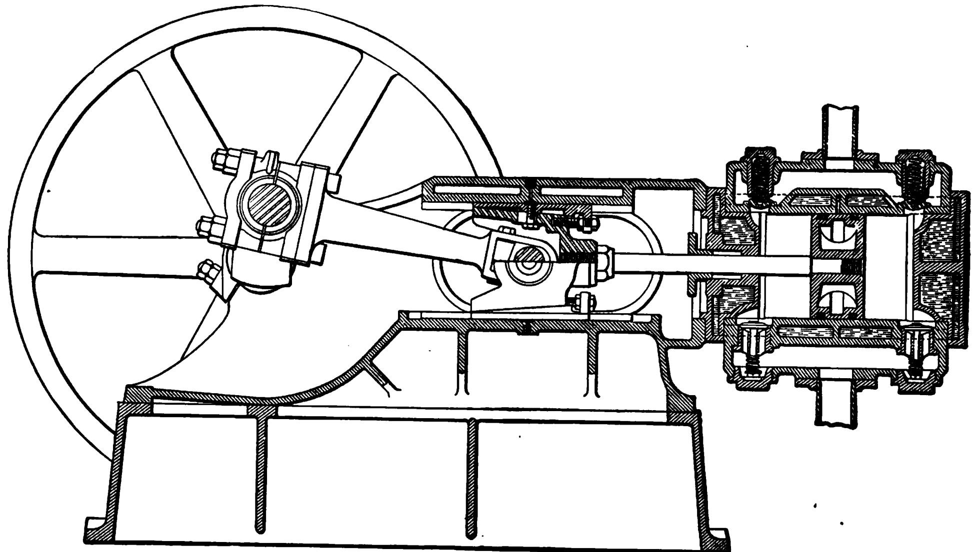


FIG. 59a.

sidered advantageous, because of the slower motion of the air-compressor valves as compared with the direct-connected outfit. In each of the illustrations the air-compressor cylinder is water-jacketed, the circulating water being supplied by the small pump actuated from the engine cam-shaft, the water being first delivered to the compressor cylinder, and thence to the oil engine cylinder. This outfit consists of 13 B. H. P. oil engine and "Ingersoll-Sergeant" double acting air-compressor having cylinder 8″ diameter and 8″ stroke, and running at 150 revolutions per minute, delivering 70 cubic ft. of free air per minute at 70 to 80 lbs. pressure.

To calculate the H. P. required to actuate an air-compressor, the diameter of compressor cylinder and length of stroke being given as well as the required gauge pressure, then the mean pressure in the cylinder must be ascertained from the table given on page 126 corresponding with gauge pressure required. The power necessary is then found by means of the following formulæ:

$$\text{H. P.} = \frac{PLAN}{33{,}000}.$$

P = mean effective pressure in pounds per square inch in cylinder as given in table.
L = length of stroke in feet.
A = area in cylinder in inches.
N = number of revolutions per minute with single-acting compressor if double-acting x 2.

TABLE II.—VARIOUS AIR PRESSURES.—RICHARDS'.

Gauge Pressure.	Absolute Pressure.	Pressure in Atmospheres.	Volume with Air at Constant Temperature.	Volume with Air Not Cooled.	Mean Pressure per Stroke. Air Constant Temperature.	Mean Pressure per Stroke. Air Not Cooled.	Mean Pressure during Compression only. Air Constant Temperature.	Mean Pressure during Compression only. Air Not Cooled.	Final Temperatures. Air Not Cooled.	Gauge Pressure.
0	14.7	1	1	1	0	0	0	0	60	0
1	15.7	1.068	.9363	.95	.96	.975	.43	.44	71	1
2	16.7	1.136	.8803	.91	1.87	1.91	.95	.96	80.4	2
3	17.7	1.204	.8305	.876	2.72	2.8	1.4	1.41	88.9	3
4	18.7	1.272	.7861	.84	3.53	3.67	1.84	1.86	98	4
5	19.7	1.34	.7462	.81	4.3	4.5	2.22	2.26	106	5
10	24.7	1.68	.5952	.69	7.62	8.27	4.14	4.26	145	10
15	29.7	2.02	.495	.606	10.33	11.51	5.77	5.99	178	15
20	34.7	2.36	.4237	.543	12.62	14.4	7.2	7.58	207	20
25	39.7	2.7	.3703	.494	14.59	17.01	8.49	9.05	234	25
30	44.7	3.04	.3289	.4638	16.34	19.4	9.66	10.39	255	30

35	49.7	3.381	.2957	.42	17.92	21.6	10.72	11.59	281	35
40	54.7	3.721	.2687	.393	19.32	23.66	11.7	12.8	302	40
45	59.7	4.061	.2462	.37	20.52	25.59	12.62	13.95	321	45
50	64.7	4.401	.2272	.35	21.79	27.39	13.48	15.05	339	50
55	69.7	4.741	.2109	.331	22.77	29.11	14.3	15.98	357	55
60	74.7	5.081	.1968	.3144	23.84	30.75	15.05	16.89	375	60
65	79.7	5.423	.1844	.301	24.77	31.69	15.76	17.88	389	65
70	84.7	5.762	.1735	.288	26.	33.73	16.43	18.74	405	70
75	89.7	6.102	.1639	.276	26.65	35.23	17.09	19.54	420	75
80	94.7	6.442	.1552	.267	27.33	36.6	17.7	20.5	432	80
85	99.7	6.782	.1474	.2566	28.05	37.94	18.3	21.22	447	85
90	104.7	7.122	.1404	.248	28.78	39.18	18.87	22.	459	90
95	109.7	7.462	.134	.24	29.53	40.4	19.4	22.77	472	95
100	114.7	7.802	.1281	.232	30.07	41.6	19.92	23.43	485	100
105	119.7	8.142	.1228	.2254	30.81	42.78	20.43	24.17	496	105
110	124.7	8.483	.1178	.2189	31.39	43.91	20.9	24.85	507	110
115	129.7	8.823	.1133	.2129	31.98	44.98	21.39	25.54	518	115
120	134.7	9.163	.1091	.2073	32.54	46.04	21.84	26.2	529	120
125	139.7	9.503	.1052	.202	33.07	47.06	22.26	26.81	540	125
130	144.7	9.843	.1015	.1969	33.57	48.1	22.69	27.42	550	130
135	149.7	10.183	.0981	.1922	34.05	49.1	23.08	28.05	560	135
140	154.7	10.523	.095	.1878	34.57	50.02	23.41	28.66	570	140
145	159.7	10.864	.0921	.1837	35.09	51.	23.97	29.26	580	145
150	164.7	11.204	.0892	.1796	35.48	51.89	24.28	29.82	589	150
160	174.7	11.88	.0841	.1722	36.29	53.65	24.97	30.91	607	160
170	184.7	12.56	.0796	.1657	37.2	55.39	25.71	32.03	624	170
180	194.7	13.24	.0755	.1595	37.96	57.01	26.36	33.04	640	180
190	204.7	13.92	.0718	.154	38.68	58.57	27.02	34.06	657	190
200	214.7	14.6	.0685	.149	39.42	60.14	27.71	35.02	672	200

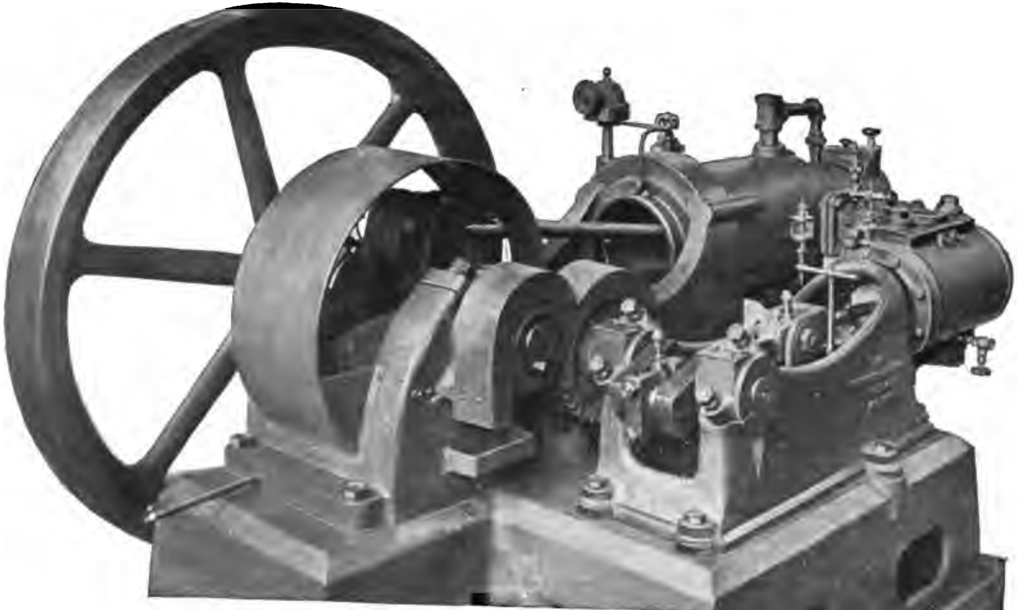


Fig. 60.

For example, in the $8\frac{1}{2} \times 8\frac{1}{2}$ inch single-acting direct-connected plant (Fig. 59), the theoretical power required to actuate the compressor is as follows:

$$\text{H. P.} = \frac{19.4 \times .78 \times 56.7 \times 230}{33,000}.$$

$$\text{H. P.} = 5.98.$$

As this represents only the power required to compress the air, additional power must also be provided sufficient to overcome the friction of the compressor. In this case it will be noted that approximately 15 per cent. is allowed.

TABLE III.—EFFICIENCIES OF AIR-COMPRESSORS AT DIFFERENT ALTITUDES.

Altitude, feet.	Barometric, Pressure.		Volumetric Efficiency of Compressor, Per Cent.	Loss of Capacity, Per Cent.	Decreased Power Required, Per Cent.
	Inches, Mercury.	Pounds Per Square Inch.			
0	30.00	14.75	100.	0.	0.
1000	28.88	14.20	97.	3.	1.8
2000	27.80	13.67	93.	7.	3.5
3000	26.76	13.16	90.	10.	5.2
4000	25.76	12.67	87.	13.	6.9
5000	24.79	12.20	84.	16.	8.5
6000	23.86	11.73	81.	19.	10.1
7000	22.97	11.30	78.	22.	11.6
8000	22.11	10.87	76.	24.	13.1
9000	21.29	10.46	73.	27.	14.6
10000	20.49	10.07	70.	30.	16.1
11000	19.72	9.70	68.	32.	17.6
12000	18.98	9.34	65.	35.	19.1
13000	18.27	8.98	63.	37.	20.6
14000	17.59	8.65	60.	40.	22.1
15000	16.93	8.32	58.	42.	23.5

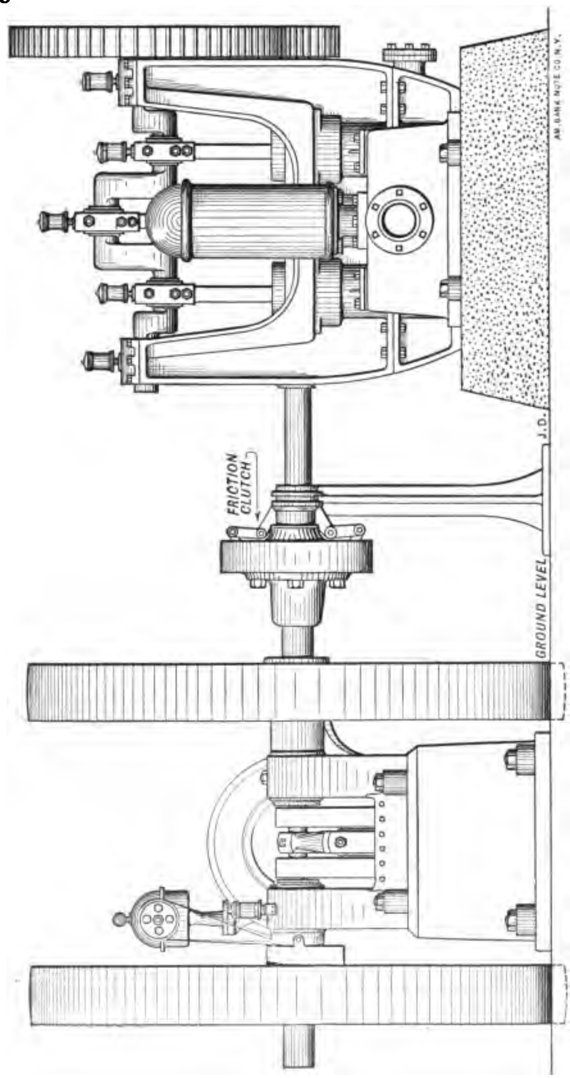


FIG. 61.

The efficiency of an air compressor is reduced when working at high altitudes. Table III. gives such depreciation in efficiency at the different altitudes.

OIL-ENGINE PUMPING PLANTS.—Fig. 61 represents an oil-engine pumping plant as installed for supplying

FIG. 62.

town or village water-supply. This outfit consists of 13 H. P. oil engine connected by friction-clutch to the shaft of a triplex pump having cylinders 6½″ diameter and 8″ stroke.

The amount of water delivered by this outfit is approximately 165 gallons per minute, with total average lift of 195 ft. The cost of fuel for running is

about 13 cents per hour. Practically, no attention is required beyond starting the engine and occasional lubrication.

Fig. 62 shows a small outfit suitable for supplying water to a country-house, and consists of $1\frac{1}{2}$ H. P. engine and pump capable of delivering 1200 gallons of water with 150 ft. total lift.

To calculate the theoretical H. P. required to raise a

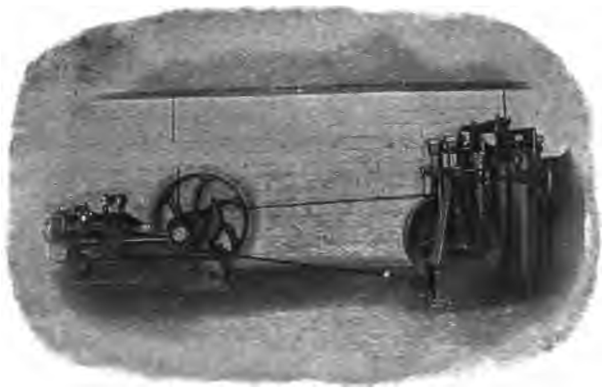


FIG. 63.

given amount of water, multiply the number of gallons to be delivered per minute by 8.3, which gives the weight; again, multiply by the total required lift in feet, and divide the result by 33,000, thus:

$$\text{H. P.} = \frac{\text{Number of gallons} \times 8.3 \times \text{height of lift}}{33{,}000}$$

Example: 165 gallons 195 feet lift

$$\frac{165 \times 8.3 \times 195}{33,000}$$

$= 8$ H. P. actually required to lift water.

The friction of the moving parts of the pump has to be overcome, and for this and other losses allowance is usually made by figuring the efficiency of the pump (in the smaller size) at 60 per cent. to 70 per cent.

Oil Engines Driving Ice and Refrigerating Machines.

Oil engines are now being used in connection with small ice and refrigerating machines.

Fig. 63 represents a plant of this description, consisting of an oil engine belted direct to a refrigerating machine used in this instance for cooling a butcher's cold-storage box.

The refrigerating machines are rated according to the amount of ice they are assumed to displace. A one-ton machine is one which will effect the same cooling in twenty-four hours which a ton of ice would do in melting. The chief advantage of the refrigerating machine is that while the ice can only produce a temperature of 35° Fahr. and upward, the refrigerating machine can be operated to produce any temperature which may be desired.

In the process of refrigeration, the work which the

oil engine has to do is to drive a compressor, and therefore the same principles may be applied to this machine as to the ordinary air-compressor already discussed. We need only to know how much gas has to be compressed and the conditions upon which to base the calculation for the work done in the compressor. It is the practice of refrigerating-machine makers to allow about 4.5 cubic ft. displacement per ton of refrigeration—that is to say, a 10-ton machine is one having capacity of pumping 45 cubic ft. of gas per minute.

In the case of the ordinary compressor, we have only to consider the final pressure, since the initial pressure is always that of the atmosphere. In the case of the refrigerating machine, however, this is not the case, for the gas being circulated in a closed circuit may have not only a varying final pressure, but also a varying suction pressure. These pressures depend upon the temperatures obtaining in the cold room and in the condenser in a manner which it is not necessary to consider in detail. The initial pressure and the final pressure being known, the mean pressure may be calculated in the ordinary way.

To facilitate this calculation, table No. IV. may be consulted. The vertical left-hand column gives the initial pressure corresponding to the temperatures named in the second column, these being the temperatures *inside* the cooling pipes. The top horizontal line gives the pressure corresponding to the temperatures in the second horizontal line. These temperatures are those obtaining in the condenser.

TABLE IV.—MEAN PRESSURE OF DIAGRAM OF GAS (AMMONIA) COMPRESSOR.

Refrigerator Pressure and Temperature.		Condenser Pressure and Temperature.								
		103	**115**	**127**	**139**	**153**	**168**	**184**	**200**	**218**
		65°	**70°**	**75°**	**80°**	**85°**	**90°**	**95°**	**100°**	**105°**
4	**— 20°**	41.46	43.91	46.34	48.77	51.23	53.68	56.11	58.54	60.99
6	**— 15°**	42.72	45.38	47.90	50.74	53.40	56.08	58.86	61.40	64.08
9	**— 10°**	44.40	47.38	50.33	53.29	56.25	59.20	62.16	65.14	68.09
13	**— 5°**	45.86	49.15	52.42	55.70	58.97	62.25	65.53	68.81	72.08
16	**0°**	46.94	50.56	54.16	57.78	61.40	65.00	68.62	72.22	75.84
20	**5°**	47.74	51.73	55.70	59.68	63.67	67.66	71.62	75.61	79.61
24	**10°**	48.04	52.40	56.77	61.13	65.51	69.86	74.24	78.59	82.97
28	**15°**	47.88	52.67	57.44	62.23	67.02	71.81	76.60	81.39	86.18
33	**20°**	47.08	52.30	57.53	62.75	67.98	73.23	78.46	83.68	88.91
39	**25°**	45.06	51.34	57.05	62.75	68.46	74.17	79.88	85.58	91.29
45	**30°**	43.16	49.71	55.92	62.14	68.35	74.56	80.77	86.98	93.19
51	**35°**	40.52	47.26	54.02	60.76	67.52	74.28	81.02	87.78	94.52

The mean pressure corresponding to any two known conditions may therefore be taken from the table; for example, with a suction pressure of 28 and a condenser pressure of 153, the mean pressure is 67.02 pounds. The work required to produce a ton of refrigeration, therefore, would be

$$H. P. = \frac{PLAN}{33,000},$$

in which

$P = 67.02$ pounds.
$L = 4.5$ feet.
$A = 144$ square inches $=$ 1 sq. ft.
$N = 1$.

Substituting these values, the horse-power is 1.32. No allowance is here made for friction, and in small refrigerating machines this should be extremely liberal.

Moreover, on reference to the table it will be seen that the machine may happen to be called upon to work under conditions where the mean pressure will be very much increased; such, for example, when the back pressure is 51 lbs. and the high pressure is 218 lbs. Under these circumstances the mean pressure will be 94.52 instead of 67.02. For these reasons it is not safe to provide for a refrigerating machine of small dimensions a power much less than about 3 H. P. per ton of refrigeration. Under ordinary conditions of running, less than this, and frequently only one-half of this will be required, but provision should be made for taking care of extreme conditions.

FRICTION-CLUTCHES.—Where engines of 10 H. P. or over are installed, it is a great advantage to have a friction-clutch pulley added. This can be attached either to the engine crank-shaft or to the intermediate or main shaft. Fast-and-loose pulleys are sometimes substituted for the friction-clutch.

With either friction-clutch or fast-and-loose pulleys the advantages gained are, first, the ease with which the engine can be started, the loose or friction-clutch pulley only instead of the whole shaft has to be turned when the plant is started, and, secondly, in case of accident or other emergency necessitating the quick cessation of the revolving machinery, this can be accomplished at once by simply moving over the handle of the friction-clutch and pulley. Otherwise without the clutch the heavy fly-wheels of the engine remain revolving for a minute or so after the fuel of the engine is turned off, and being directly connected by belt to the shafting and machinery, the whole plant is in motion while the momentum of the fly-wheels exists.

Friction-clutches are made of various designs by several manufacturers. That shown in Fig. 63*a* is especially adapted for explosive engines. It consists of a carrier which bolts to the regular bosses on the fly-wheel of the engine, this carrier acting as the journal of the pulley, and the mechanism of the clutch is enclosed in the same. The clutch has a side grip. The pulley, otherwise loose, is thrown into connection with the engine fly-wheel by simply pushing in a spindle on which a hand-wheel revolves loosely. Two rollers are mounted on the end of the spindle, and bearing on

these rollers are the levers which in turn are pivoted to the gripping plate and a lug on the levers abuts against the adjusting screw. The inward movement of the spindle forces these levers apart and draws the gripping plate in, thus gripping the pulley in a circular vise

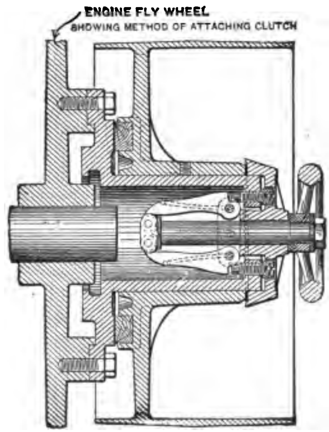


FIG. 63*a*.

between the flange on the carrier and the gripping plate. To release the clutch the spindle is pulled out, and thereby the strain on the levers is removed, thus allowing the pulley to run loose. This clutch is known as the B and C Friction Clutch Pulley.

CHAPTER VII.

INSTRUCTIONS FOR RUNNING OIL ENGINES.

THE attendant, in order to obtain the best results from an engine, should first fully understand the principle by which the engine he is running works and the conditions which it is essential should exist in the cylinder to procure proper explosion and combustion. These conditions are practically the same in all types of oil engines. The explosive mixture consists of hydrocarbon gas and atmospheric air, the gas being formed from kerosene oil previously gasefied or vaporized and properly mixed with air by one or other of the different methods, as described in Chapter I. This mixture is then compressed by the inward stroke of the piston before ignition with the two-cycle type of engine. The mixture is afterward ignited by hot tube, electricity, heated surfaces, or otherwise, as also described in Chapter I., and the required impulse is then obtained at the piston. If for any reason these conditions are not existing, proper explosion and combustion will not follow. The several reasons which prevent proper explosions being obtained are very fully described in Chapter III. on "Testing."

The conditions necessary to insure proper working are as follows:

(*a*) Oil supply to the vaporizer or combustion chamber delivered at the correct time, and in such quantity as to form proper explosive mixture. Efficient supply of air.

(*b*) Sufficient pressure in the cylinder by compression before ignition.

(*c*) Correct ignition of the gases, the ignition taking place at the proper time.

CYLINDER LUBRICATING OIL.—It is essential that a suitable lubricating oil be used for the piston. The great heat evolved in the cylinders of explosive engines renders this essential.

The lubricating oil recommended for this purpose is a light mineral oil having a flash point of not less than 360° Fahr. and fire test 420° Fahr. Gravity test 25.8, and having a viscosity of 175 (Saybold test). If waste-oil filter is used, the oil filtered must not be employed for lubricating the piston at any time.

The following are instructions as formulated by the makers of the different engines, each of the four types of vaporizers being here represented, as well as the different kinds of igniting devices.

HORNSBY-AKROYD TYPE.

The method of working is explained in Chapter IX., giving general description of these engines. The oil-tank in the base of the engine should be filled

and the oil pumped up by hand until it passes the overflow pipe. The water-tanks if used must also be filled to the top and the cylinder water-jacket also be full of water before starting.

Preparing to Start the Engine.—On those engines in which the vaporizer is partially water-jacketed, the valve on the inlet water-pipe should be closed before commencing to heat the vaporizer for starting, and opened, or partially opened, when running.

To Heat the Vaporizer.—A coil lamp is used (see illustration, Fig. 64) for this purpose; the lamp reservoir should be nearly filled with oil. A little kerosene should then be poured into the cup containing asbestos wick under the coil and lighted. When this has nearly burnt out, pump up the reservoir with air by the air-pump, when oil vapor will issue from the small nipple, and on being lighted will give a clear flame. When it is required to stop the lamp, turn the little thumb-screw on the reservoir-filling nozzle and let the air out, and remove the lamp from the bracket. The nipple at any time can be cleaned with the small prickers which are supplied for this purpose. Should the U-tubes get choked up, the lower one can be gotten at by unscrewing the joint just below it, and the other one by screwing out the nipple from which the oil vapor issues. The heating of the vaporizer is one of the most important duties to be attended to, and care must be taken that it is made hot enough before starting. The attendant must see that the lamp is burning properly for five or ten minutes, or sometimes a little longer, according to the size of the engine. If, however, the

lamp is burning badly, it may take longer to get the proper heat. It is most important that the lamp should be carefully attended to.

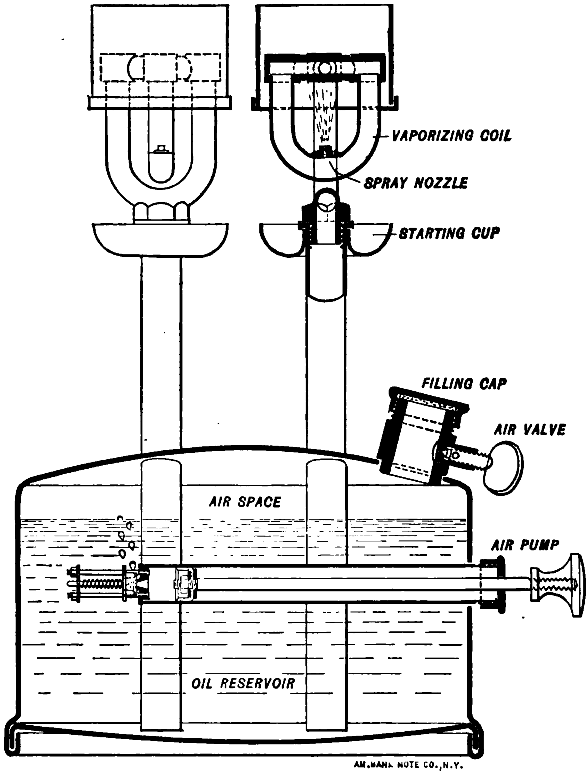


FIG. 64.

TO START THE ENGINE.—Place the starting handle to position "Shut," and work the pump-lever up and down until the oil is seen to pass the overflow-valve.

Then turn the handle to position "Open," work the pump-lever up and down again, one or two strokes, then give the fly-wheel one or two turns, and the engine will start readily. There is also a handle upon the cam-shaft, which, when starting the engine, must be placed in the position marked "To Start," and immediately the engine has gotten up speed this handle should be placed in position marked "To Work."

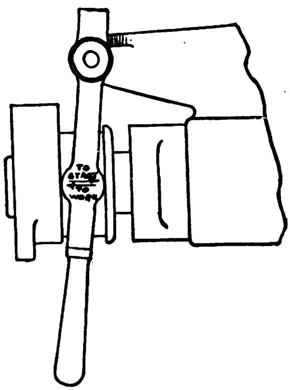


FIG. 65.

(See Fig. 65.) When it is required to stop the engine, turn the starting handle to the position marked "Shut." If too much oil is pumped into vaporizer before starting it will be difficult to start up.

OILING ENGINE.—See that the oil-cups on the main crank-shaft bearings are fitted with proper wicks and with other oil-cups are filled with oil. Oil the

small end of the connecting-rod which is inside the piston, also the bearings on horizontal shaft and the skew-gearing, the rollers at the ends of the valve-levers and their pins, and the pins on which the levers rock, the governor spindle and joints, the bevel-wheels which drive same, and the joints that connect the governor

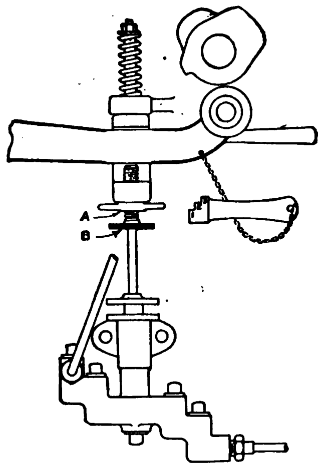


FIG. 66.

to the small relief-valve on the vaporizer valve-box. For such purposes, none but the best engine oil should be used.

OIL-PUMP.—When the engine is working at its full power the distance between the two round flanges *A* and *B* on the pump-plunger should be such that the gauge " 1" will just fit in between the flanges. (See

Fig. 66.) The other lengths on the hand-gauge marked "2" and "3" are useful for adjusting the pump to economize oil when running on a medium or a light load. Do not screw down the pump packing tight enough to interfere with the free working of the plunger.

Running Engines Light or Nearly So.—When engines are required to run with light or no load, it is best to alter the stroke of the pump to supply only sufficient oil to keep the engine running at full speed, so that the governor occasionally reduces the oil. The inlet water-pipe to the vaporizer-jacket should be closed when running light also.

Air-Inlet and Exhaust Valves.—See that the air-inlet and exhaust valves are working properly and drop onto their seats. They can at any time, if required, be made tight by grinding in with a little flour of emery and water. The set-screws at the ends of the levers that open these valves must not be screwed up so high that the valves cannot close; this can be ascertained by seeing that the rollers at the other end of the levers are just clear of the cams when the projecting part of the cams is not touching them. (See Fig. 67.)

Vaporizer Valve-Box.—In this box there are two valves. The vertical one is regulated by the governor, and when the engine runs too fast the governor pushes it down, thus opening it and allowing some oil to overflow into the by-pass, which should only allow oil to pass when the governor presses it down, or when the starting handle is turned to "Shut." The horizontal

valve in this box is a back-pressure valve, and should a leakage occur it may be discovered by slightly opening the overflow-valve (by pressing it down with the hand), when, if there is a leakage, vapor will issue from the overflow-pipe, and in that case the valve should be examined, and, if necessary, be taken out for inspection and ground on its seat with a little emery flour and water. If the horizontal valve and sleeve are taken out, care should be taken, in replacing them, to use the same thickness of jointing material as before.

Oil-Pipes.—The pipe from the pump to the vaporizer valve-box has a gradual rise from the pump; if

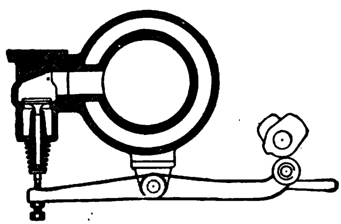


Fig. 67.

otherwise, an air-pocket would be formed in which air would be compressed upon each stroke of the pump, and thus allow the oil to enter slowly and not as it should do, suddenly. If the oil gets below the filter at any time, work the pump by hand a few minutes, holding open the overflow-valve in the vaporizing valve-box, so as to get the air well out of the pipes. The oil-filter should be taken out and cleaned occasionally.

Spray Holes.—It may be desirable to take off the vaporizer valve-box and clean the little hole or holes through which the oil issues. The reamers, or small wires supplied, are not for increasing the size of the hole, but are simply for cleaning it at any time.

Testing Oil-Pump.—See that the pump gets its proper oil supply. Disconnect the oil-supply pipe union attached to vaporizer valve-box, and give the

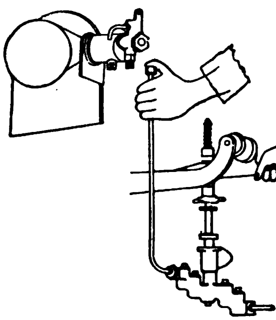


Fig. 68.

pump two or three strokes so as to pump oil up; then press the thumb firmly on the end of the pipe, as shown in illustration, Fig. 68. Pump both by a sudden jerk, and afterward by a steady pressure. If the plunger yields to a sudden jerk and no oil has gotten past the thumb over the top of the delivery-pipe, then the pump or the pipes contain air. If the plunger does not yield to a sudden jerk, but slowly falls under a constant pressure, then the suction-valves of pump are

not tight. If necessary, the valve-seats can be renewed by lightly driving the cast-steel ball valves onto their seats with a small copper punch. If it is required to see that the vaporizer valve-box is in order, take off the vaporizer valve-box body and sleeve, and connect them to the oil-supply pipe from the pump, so that the jet from the spraying hole can be directed where it can be seen. Work the pump by hand, when the jet produced should be clear, with distinct and abrupt pauses between each delivery.

THE GOVERNOR "HUNTING."—This may be caused by the joints or spindle of the governor becoming bent, dirty, or sticky, and requiring cleaning. If the pump is not giving a regular supply of oil, it may sometimes cause the governor to hunt, and the engine would run irregularly. This may occur when the engine is first started.

THE CROSSLEY PATENT TYPE.

STARTING.—Heat the ignition-tube by means of the lamp in the usual way. The pressure (about 60 lbs.) necessary to raise the oil to the lamp in this engine is taken from the oil-tank, the air pressure before starting being created by hand. This lamp heats both the ignition-tube to a good red heat and vaporizer blocks to less heat simultaneously. The necessary pressure to raise the oil to the lamp is maintained by the pump actuated from the cam-shaft when the engine is running.

PRIMING CUP.—Fill the little brass priming cup on

the top of the vaporizer cover with oil; open the valve and let the oil pass through into the vaporizer, and then shut it again. Leave the wire on the chain out of the measurer. Place the exhaust roller over to engage with the one-half compression cam; turn the fly-wheel until the crank-pin is about one inch above the horizontal (both valves being closed); open the stop-valve on the end of air-receiver; connect up the oil-pump by replacing the back-pin, having first made a few strokes with the hand-pump until the oil-pipe is full up to the measurer, and turn the quadrant on air-throttle valve. The engine is now ready to start, and the air under pressure from receiver may be let in. Loosen the screw of starter valve; open the valve by means of the loose lever, and hold open until the crank has just passed the vertical position. This impulse will be sufficient to turn the fly-wheel a few times, during which the piston will receive regular impulses. The exhaust roller may then be moved off the one-half compression, when full speed will be steadily attained.

As soon as convenient the screw on the starting valve may be unscrewed to allow the receiver to become recharged again. Should the engine miss explosions and fail to attain full speed, then turn the lid of measurer partly around and give a little extra supply of oil from a hand-can.

Air Supply.—At full speed the air-throttle must be opened to admit more air, and the amount must be judged as to whether the engine ignites its charges or not; too much air will cause it to miss fire—too little air causes too sharp firing. If the receiver is not

charged, and it is required to start engine by hand, pull around the fly-wheel and get up as much speed as possible before putting the governor blade in position for engaging with the governor mechanism which opens the gas-valve.

VAPORIZER BLOCK.—The vaporizer block must be well heated previous to starting; otherwise unvaporized oil will be carried over into cylinder, and thus make starting uncertain until the oil has all passed away in evaporation. This may also cause puffs of vapor to rush out of the air inlet at the top of the chimney, preceded by a slight explosion in the vaporizer block. This is caused by late ignition in cylinder, and is due to insufficient vaporization or to the ignition-tube not being hot enough.

VAPOR VALVE.—If small puffs of vapor issues out of the air-pipe of the chimney every other revolution while the engine is running, it is a proof that the vapor-valve is not tight and must be cleaned and ground on its seating.

CAMPBELL OIL ENGINE.

STARTING.—Before starting the engine, see that the vaporizer is thoroughly well heated. The lamp under the vaporizer should burn with a long, bright flame. When the vaporizer is sufficiently heated, throw the governor drop-lever down, thus holding the exhaust-valve open and relieving the compression. While this lever is held down, give a quarter or a half turn of the

oil-cock; then turn the fly-wheel quickly four or five revolutions, and allow the governor drop-lever to be free. It will swing up clear of the exhaust-lever and allow a charge of air and oil to be driven into the vaporizer; the engine should then commence working. After the engine has started, turn on a little more oil. If the oil taken into the vaporizer should not explode properly, the oil-cock must be shut and opened again quickly to allow any superfluous oil which has lodged in the vaporizer to be drawn out of it and vaporized. When using a heavy oil, open the inlet-valve to allow more air to flow into the vaporizer.

AIR AND OIL SUPPLY.—Too much oil passing to the vaporizer will cause the engine to miss exploding or to explode irregularly. To increase the air supply, slacken the nuts and tension of air-inlet valve; by tightening the nuts and spring, the air supply is decreased.

IGNITION-TUBE.—See that the inside of the ignition-tube is kept clear from oil, and keep all the valves clean and the governors free from oil and dirt. When the engine is running properly, the quantity of oil required is the same, whether the engine is running at light or heavy load.

GOVERNORS.—The governors cut out some of the charges at light loads and admit more charges of oil at heavy loads; each charge, however, has the same composition of vapor and air.

The Priestman Type.

Starting.—Open the drain-cock in the vaporizer and see that the vaporizer contains no oil; then close the cock. Fill the oil-tank to the small upper-pet cock, through the strainer provided and screw down the relief air-valve. Lubricate the piston wrist-pin and the crank-bearing between the fly-wheels. Drop a little oil on the pump-piston and in the oil holes of the bearings of the large gear-wheels, the eccentric, and all other bearings. Mineral oil must not be used on the governor oil spindle which projects into the spray-maker.

Electric Igniter.—Raise the electric fork-handle slightly. This is done in order to produce the igniting spark somewhat later for starting than is required when the engine is running at full speed. Turn the fly-wheels forward until the small knob on the cam-shaft has just passed the contact with the forks, and the crank-pin is then just clear of the large gear-wheel.

Heating Vaporizer.—Heat the vaporizer until the lower part of the feed-pipe leading to the inlet-valve is too hot to be comfortably held by hand. When the vaporizer is sufficiently heated, pump up 6 or 8 lbs. gauge air pressure in the oil-tank with the hand-pump; open the oil-cock, and then give the fly-wheels a few turns with the starting handle. After starting, move the electric fork-handle down as far as it will go.

Air Supply.—Set the air-relief valves for giving about 8 to 10 lbs. air pressure in the oil-tank. The most suitable running pressure in a given locality as indi-

cated by the gauge, has to be determined by experiment. With the air pressure too low or too high, the engine may miss explosions. The best test for this is the color of the ignition-plug. When the pressure is right, the plug will be perfectly clean. If the plug is coated with an oily black substance, it is a sign of too much oil—that is, too high a pressure. To stop the engine, turn off the oil-cock. When stopped, see that the electric circuit is not closed, or the battery energy will be wasted.

General Remarks.—If an oil engine is working properly and efficiently, it should run smoothly to the eye, without knocking either in the cylinder or bearings. The piston should continue to work clean and be well lubricated, without any apparent carbon or gummy deposit. The exhaust gases at the outlet-pipe should be invisible or nearly so. The explosion should be regular and should be only reduced in pressure when the governor is reducing the explosive charge and allowing only part or none of the charge of oil to enter the cylinder.

If the piston is black and gummy, or if the exhaust gases are like smoke, then the combustion inside the cylinder is recognized as being incomplete, and the cause should at once be ascertained and remedied.

Bad combustion may be due to several reasons, but is chiefly caused by improper mixture of air and gases in the cylinder, due either to too much oil entering into the vaporizer or to insufficient amount of air being drawn in mixed with the hydrocarbon gas. To remedy this defect, examine the oil-inlet valves or spraying de-

vice carefully; also see that air and exhaust valves are allowed to drop freely on their seats, and that springs or other mechanism for closing the valves are in good shape. Examine piston-rings and ascertain that the rings are in good order and are not allowing leakage of air to pass them.

REGULATION OF SPEED.—To alter speed of the engine with the hit-and-miss type of governor, the spring is strengthened or the weight reduced to increase speed. The weight is effectively increased by moving it toward the end of the lever away from the fulcrum-pin, and *vice versa* to reduce speed. The strength of the spring is increased by tightening down the thumb-screw nut. With the Porter type of governor where counterbalance with movable counterweight is provided, the speed is accelerated by increasing the supplementary weight, or by placing it nearer the end of the lever. If the centrifugal force of the revolving weights is controlled by a spring instead of weight, then the speed is increased by strengthening the spring.

REVERSING DIRECTION OF ROTATION.—In order to reverse the direction of rotation of an explosive engine, it is necessary to change the relative position of the cams actuating the air and exhaust valves and fuel supply so as to alter the periods of opening and closing of these valves, and also to change the period of fuel supply. In those engines in which one cam controls both the air-inlet valve and the fuel supply, the shifting of this one cam alone effects the change necessary.* Where the fuel supply is operated separately, the cam

*The position of the exhaust cam to conform to the diagrams in Fig. 69 is changed by alteration of the gearing in the cam shaft.

or eccentric controlling this mechanism must be moved correspondingly with the air-valve cam.

The following diagrams give the correct positions

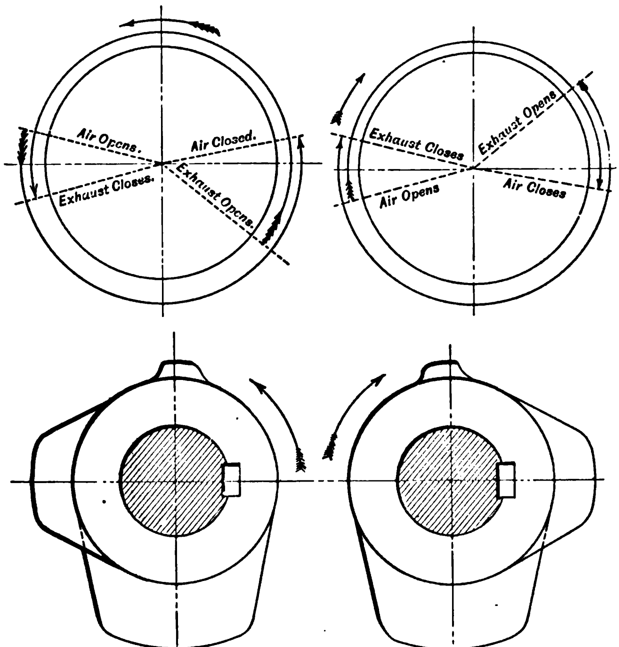


FIG. 69.

of the opening and closing of the valves when the engine is running in each direction, and the cams as set for each case are shown in Fig. 69, the slot for key-way in the air-inlet cam having been changed only.

Where the air-inlet valve is automatic and the exhaust valve only is actuated from the crank-shaft, then, to reverse the direction of rotation of the crank-shaft, the position of the exhaust-cam only is changed, corresponding to the position as marked for the exhaust valve in diagram shown in Fig. 69.

The lip for regulating the compression when starting the engine only, which is usually found on the exhaust cam, will require adjustment when the engine is reversed so as to close the exhaust valve when approximately one-half the compression stroke has been completed. The direction of rotation for which the cams of the engine are adjusted can be ascertained by turning the fly-wheel until the exhaust cam commences to open the exhaust valve. If the exhaust valve is opened when the crank-pin is above the outward centre, as shown on the diagram to the right in Fig. 69, then the direction of the engine is "over" or away from the cylinder. When the exhaust valve opens below the centre of the crank-pin, as shown in diagram to the left in Fig. 69, then the direction of rotation of the fly-wheel will be "under"; that is, the upper part of the fly-wheel will revolve toward the cylinder.

CHAPTER VIII.

REPAIRS.

Oil Engines as made by most of the makers are of substantial construction, with ample bearing surfaces, and consequently require few repairs. The lower initial pressures of explosion evolved in oil engines as compared with some gas and gasoline engines considerably lessens the severe shock to the piston and to the crank-shaft bearings and connecting-rod bearings. All machinery requires repairs more or less according to the care that it receives, and oil engines are not an exception to this rule.

The Piston should be drawn out occasionally; this is done by uncoupling the connecting-rod crank end bearings and pulling the piston out. Chain-block is sometimes added to the installation of large engines, and it is a very useful adjunct when it is required to take out the piston or when other repairs have to be made. Where no arrangement of this kind is available when the piston is to be taken out, wooden packing is placed in the engine-bed, on which the piston can rest as it is drawn out. Care should be taken that the weight of the piston as it is drawn from the cylinder does not fall on the piston-rings or they may thus be broken.

With the vertical type of engine the piston is taken out from the top, the cylinder head and other parts having been removed.

The piston should be washed with kerosene and well cleaned. When putting piston back in place, each ring should be put separately in exact position in its groove as regards the dowel-pin in piston groove before the ring enters the cylinder. The piston, the rings, and the inside of the cylinder must all be carefully cleaned and well lubricated with proper oil before being again put in place. Where the rings require cleaning, this can be accomplished by washing with kerosene. If, however, the piston-rings are to be taken off the piston, they must be separately sprung open by having pieces of sheet metal about 1-16″ thick and about ½″ wide inserted between ring and body of piston.

Air and exhaust valves should also be periodically taken out, cleaned and examined, and, if necessary, reground in. Powdered emery or glass powder is considered satisfactory to grind the valves in with.

Care should be taken, in replacing valves, that they are clean and free from rust or carbon, and are allowed to drop on their seats freely and do not stick in their guides.

The crank-shaft bearings will periodically require taking up as they show signs of wear and commence to knock or pound. Usually, for this adjustment, liners are left between the cap and the lower half of bearings. These liners can be occasionally reduced in thickness, so that the cap is allowed to come down close on to the shaft. Great care must be taken, in

tightening down the bearing again after adjustment, that it is not bolted down too tight on the shaft bearings; otherwise heating will result and the bearings and journal may be cut and damaged in running.

The connecting-rod bearings will require adjustment more often than the crank-shaft or main bearings.

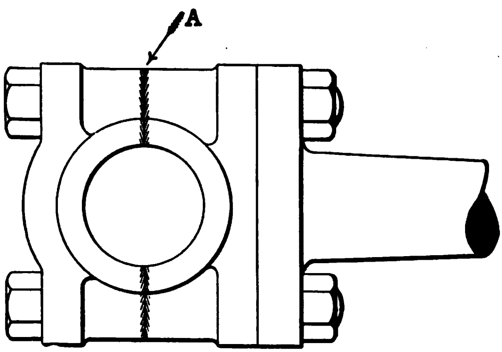


FIG. 70.

When this is necessary, the engine will be heard to knock at each revolution, and then the bearing should be taken apart at the crank-pin bearing and about 1-64″ filed off. (See *A*, Fig. 70.) As with the crank-shaft bearings, great care, in putting bearing back in place, must be exercised, first to see that it is thoroughly clean and free from dirt, and also, when readjusted, that it has a slight motion sideways and can thus be moved by hand.

When fitting new piston-ring, it is well to place the

ring in the cylinder correctly; it should have slight space, about 1-64″ left for the expansion between the joint which will take place when heated in working.

After fitting new worm or spur gearing to the valve motion, the positions of the cams should be tested by turning the fly-wheel over by hand. The correct positions of the cams are shown on diagram, Fig. 32.

The oil-filter requires occasional renewing; this can be made of muslin placed between wire gauze, as shown in Fig. 28. The oil-supply pump-valves, if they consist of steel balls, can be refitted to their seats by being tapped when in place with copper plug or piece of wood. When renewing governor parts, care must be taken that the new part is free and works without friction; this is very essential where close regulation of speed is required.

CHAPTER IX.

OIL ENGINE TROUBLES.

THE requirements for proper working of the oil engine have been already mentioned in Chapter VII. as follows: Proper oil and air supply to the cylinder or vaporizer, proper mixture or combination of air and vapor, correct and properly timed ignition. Defects which may cause improper working have also been referred to in Chapter III. on testing.

The following remarks are chiefly applicable to the operator, and refer to difficulties which may possibly be encountered in the actual use of the oil engine.

TROUBLES OF IGNITION.

THE ELECTRIC IGNITER.—This igniter is described in Chapter I. Failure in operation is generally due to the following causes:

BREAKAGE IN ONE OR OTHER OF THE ELECTRICAL CONNECTIONS.—To discover the breakage test with a length of wire in the hands bridged across between the terminals of the connection which is thought to be defective, the circuit through the cam-shaft being closed. If a spark is then given off the defect has been located and a new connection should be put in place. In

some instances a spark is not produced because the battery is run down; this defect can be ascertained by testing the battery with a small volt meter or by bringing both terminals in contact one with another from the battery; a strong spark should then be seen. If the battery is run down, it must, of course, be recharged or renewed. The terminals in the cylinder must always be clean and free from carbon deposit. This is important especially with a jump-spark plug igniter, as the terminals in the cylinder will sometimes become carbonized or corroded, thus forming a path for the current to flow across without causing any spark.

Failure to obtain electric spark ignition may occur from bad insulation of the plug. In this case a new plug should be substituted for the defective one. In some instances the electric spark is not procured because the plug is short-circuited, due to moisture. To overcome this the plug must be thoroughly cleaned and dried out or a new plug must be substituted. With the type of igniter having movable electrode, owing to friction or carbonizing, the two electrodes may be prevented from touching. In this case the moving electrode should be eased or cleansed and allowed to come freely in contact with each other.

The timing of the ignition with the electric igniter is regulated by altering the time of contact. The period of ignition varies according to the speed of the engine. With a high speed the ignition should take place just before the crank-pin arrives at the dead centre; with a slow-speed engine the time of ignition can be slightly later; that is, the ignition may take place as the crank-

pin passes the dead centre. When starting the engine, the ignition is retarded until the normal speed of the engine is attained.

TUBE IGNITER.—Troubles with this form of igniter are generally due to corrosion internally of the tube. This is remedied by taking the tube out and thoroughly cleaning it. In other instances ignition is not obtained because the tube is not properly heated. The temperature of the tube should be maintained at a good red heat. With the tube igniter it is essential that the gases can properly enter it. The timing of ignition with this form of igniter can be varied by changing the length of the tube or by altering the part of the tube which is heated. If an earlier ignition is required, the tube should be heated nearer to the cylinder end, or a shorter tube should be used. If it is required to retard the time of ignition, the tube can be heated further from the cylinder, and accordingly the gases to be ignited will not come in contact with the heated part so rapidly.

AUTOMATIC IGNITER.—In order to procure proper ignition with this form of igniter, it is essential that the compression of the air and gases is efficient. This pressure varies in different types of engines, and, as will be seen from the indicator cards shown in Chapters III. and X., is from 50 to 70 lbs. The mixture of air and oil vapor must also be correct. Failure to obtain an ignition with this type of engine is usually due to too much oil having been allowed to enter the vaporizer or cylinder, or to the fact that no oil at all has entered the vaporizer, or, as already stated, to fail-

ure to obtain proper compression. Ignition, of course, cannot be obtained when starting unless the vaporizing chamber or retort has been properly heated.

Oil Supply.—If the oil supply is defective, the fault can be ascertained by careful examination. Disconnect the oil-supply pipe and see that oil flows freely from the tank. Sometimes the oil filter in the tank will become clogged and will not allow the oil to flow through it. If oil is supplied by a pump, then test the pump, as shown on page 147. Failure of the pump to operate properly is due to leaky valves or to the packing around the plunger, allowing air to leak by, and thus the proper pressure in the pump is lost.

The oil supply may fail by reason of leakage in the oil pipes. This may easily happen where the oil tank is placed below the level of the engine and the oil has to be raised from the tank by pump. In such a case the engine may operate when the pump is working at full stroke, whereas otherwise no oil will be delivered to the cylinder or vaporizer.

Air Supply.—Defective air supply is due to leakage in the piston-rings, piston, or to leakage in the air and exhaust valves. The compression in the cylinder is, of course, governed by the air supply, and a leakage in the valves or piston can be tested by simply turning the engine backwards. With proper compression it should be difficult to turn the crank-pin past the inward dead centre during the compression period.

Knocking.—An engine working properly should be quiet in operation. Knocking may be due to either loose bearings in the connecting-rod, piston or crank-

pin end, to loose fly-wheel keys, or to improper timing of ignition. The first two defects can be ascertained by examination. The timing of ignition is most easily ascertained from the indicator card. (See page 76.)

Loss of Power.—This may be due to increased friction in the engine, which friction may be caused by bad lubrication of the piston or the piston becoming gummed up, due to improper combustion or to the use of improper lubricating oil. (See page 140.) Loss of power may also be due to heated bearings. Either of these causes can be easily ascertained. Insufficient oil or fuel supply due to the wearing of the moving parts and consequent reduction of the pressure of explosion is sometimes responsible for the loss of power. To overcome this the supply of fuel can be slightly increased. That the proper amount of fuel is being supplied can be roughly ascertained by the color of the exhaust gases. If too much oil is supplied the exhaust gases will be plainly visible. With the correct oil supply the exhaust gases will be invisible or nearly so.

Piston Blowing.—This is due to the various following causes: Improper lubrication, to the piston-rings leaking, to the piston-rings having become clogged, or to the cylinder having become cut or worn. It is also sometimes due to over-expansion of the cylinder, caused by over-heating and insufficient water supply. If the blowing of the piston cannot be remedied by proper lubrication or by thoroughly cleaning the piston-rings new piston-rings must be put in place. In some cases it is even necessary to re-bore the

cylinder and have new piston and rings. The blowing of the piston may be also caused by improper combustion due to too great an oil supply or insufficient air supply. Escape of vapor from the open end of the piston, which is thought to be a leakage, is sometimes caused by the splashing of the oil on the overheated bearings or the heated portion of the piston. This can be ascertained by stopping the engine. If vapor continues to escape when the engine is at rest, its cause is apparent, and then the supply of lubricating oil to the cylinder can be reduced.

EXPLOSIONS IN THE MUFFLER OR SILENCER.—A loud report may sometimes be heard, caused by the explosion in the exhaust pipe or muffler. This is due to the gases passing through the cylinder unconsumed and then becoming ignited in the silencer. It is not possible to create a dangerous pressure in this way, and as the silencer is usually a heavy cast-iron chamber and always open to the atmosphere, the worst result is annoyance of the noise. Explosions in the silencer or exhaust pipe can be obviated by reducing the oil supply, and are often caused by starting the engine before the igniting apparatus is sufficiently heated to cause proper ignition.

LEAKAGE OF WATER.—Engines will sometimes refuse to operate due to this cause. Leakage of water can easily be ascertained by examination of the piston and cylinder, or the piston can be withdrawn from the cylinder. Testing of the water-jackets has already been explained in Chapter III., and the leakage, if found, must be remedied by new joints. If such leak-

age is due to defect in the casting, it can sometimes be remedied by drilling out the defective material and by tapping and plugging the cylinder walls or other defective part. This work, however, requires considerable care to thoroughly overcome the leakage.

CHAPTER X.

VARIOUS ENGINES DESCRIBED.

THE CROSSLEY OIL ENGINES.

FIGURE 71 represents recent design of high-speed electric-light oil engine of 25 effective or brake H. P. This special type of engine is fitted with one heavy fly-wheel on extended shaft and outside bearing instead of the two fly-wheels, one on each side of the engine, as arranged in the smaller sizes. The method of vaporizing and igniting used with the Crossley engine is fully described in Chapter I. devoted to that subject.

The fuel oil-tank is placed against the cast-iron base of the engine, and the oil is pumped to the vaporizer in the usual way by an oil-pump actuated by the cam-shaft and in regular fixed quantities, but the fuel is allowed to enter the vaporizer only in exactly the proper quantity, the oil supply being controlled by the special measuring device, which consists of an inlet automatic valve leading to the vaporizer and an over-flow-pipe leading back to the oil-tank. If the oil supply from the pump at any time is greater than the amount of oil which should enter the vaporizer, the fuel is re-

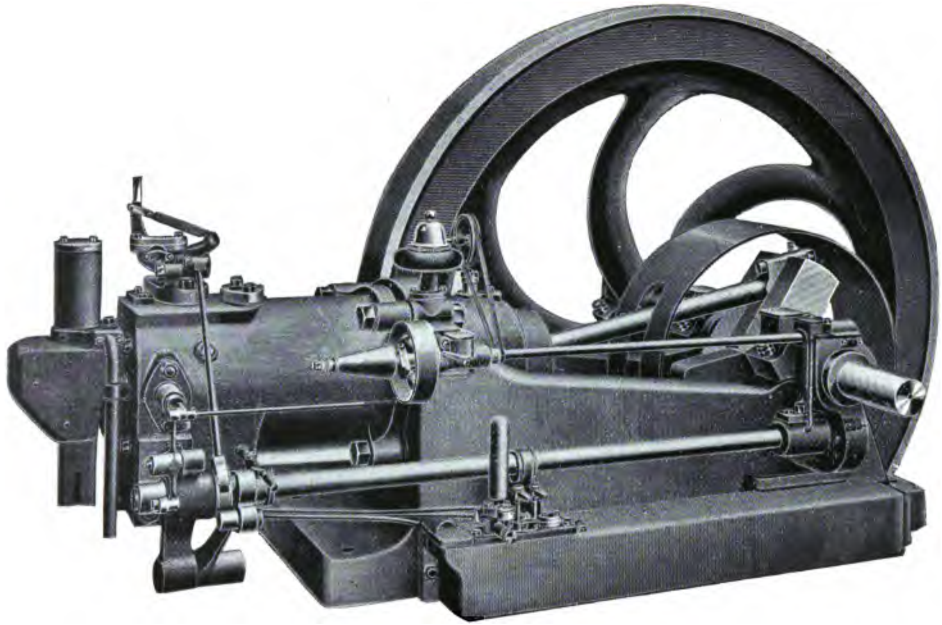


FIG. 71.

jected by the oil-measuring device, which is actuated by the partial vacuum in the cylinder during the air-

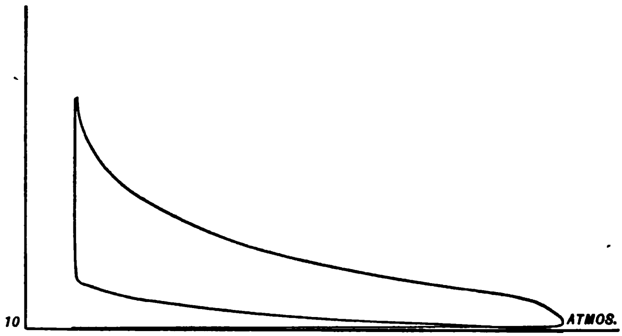


Diagram from the Crossley Engine: Revolutions per minute, 180; M. E. P., 69 lbs.; compression pressure, 48 lbs.; maximum pressure, 240 lbs.

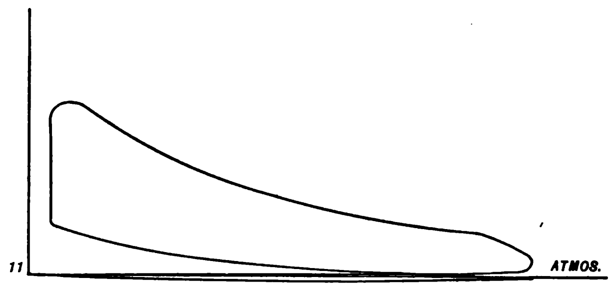


Diagram from Crossley Engine: Revolutions per minute, 180; M. E. P., 50 lbs.; compression pressure, 50 lbs.; maximum pressure, 180 lbs.

suction period. The oil then returns through the overflow-pipe to the tank.

The centrifugal governor is actuated by separate gearing and horizontal shaft direct from the crank-

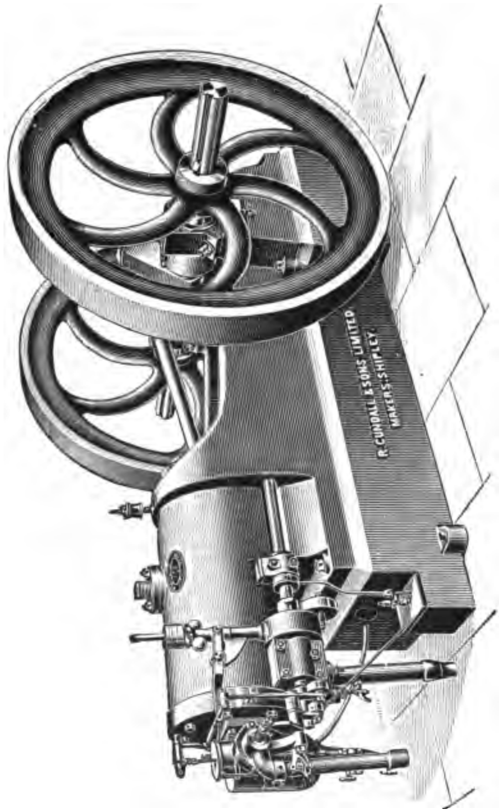


FIG. 72.

shaft, and the governor regulates the speed of the engine by acting on the hit-and-miss system, and con-

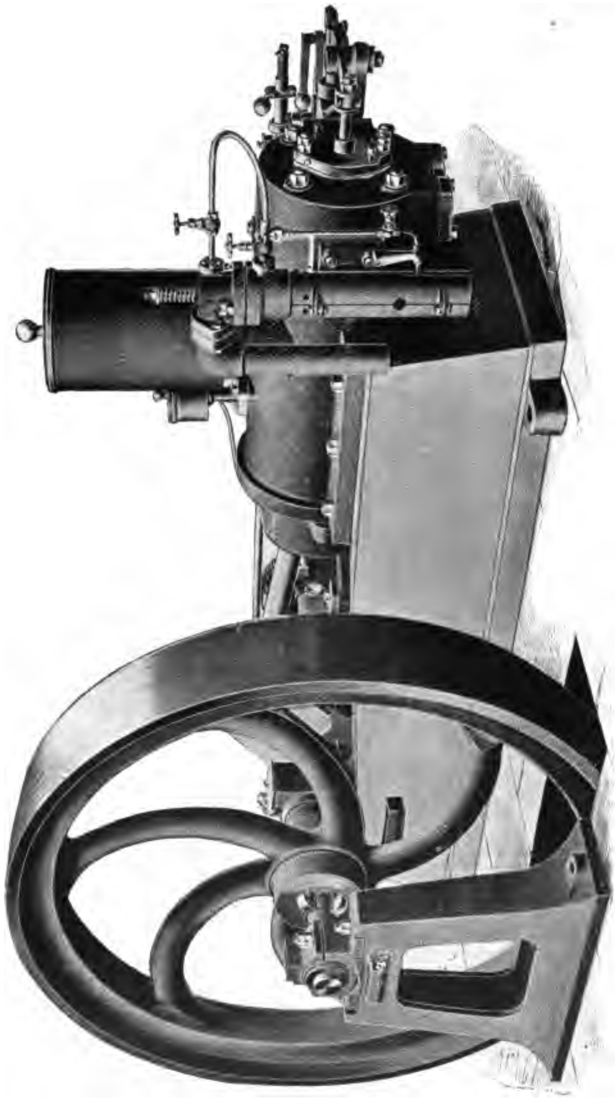
trols the vapor inlet-valve to the cylinder. Thus, if the required speed of the engine is exceeded, the vapor-valve is not opened, and accordingly only air is drawn into the cylinder through the air-inlet valve on the top of the cylinder, which is actuated by eccentric from the cam-shaft. No oil vapor is drawn into the cylinder, and the next explosion is missed. The lamp for heating the vaporizer receives its supply from the oil-tank placed against the base of the engine. The oil for the lamp is supplied by a separate pump, both oil-pumps being actuated from the same eccentric.

THE CUNDALL OIL ENGINE.

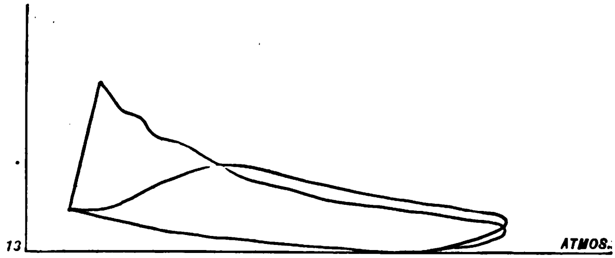
This oil engine is illustrated in Fig. 72, and it has oil-tank in the cast-iron base of engine, the fuel being pumped to the vaporizer in the usual way, the oil supply being regulated by a small adjustable thimble inside the cup on the vaporizer. The vaporizer and tube are heated by separate lamp supplied from oil-tank placed above the engine by gravity feed. Both air and exhaust valves are actuated from the horizontal cam-shaft in the usual way. The centrifugal governor is operated by bevel-gearing from the cam-shaft and controls the speed by acting on the oil-inlet valve.

THE CAMPBELL OIL ENGINE.

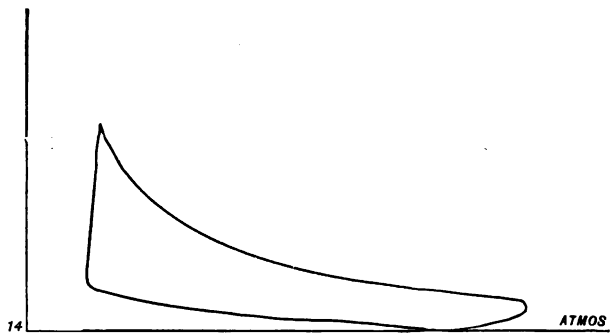
Fig. 73 illustrates larger-sized engine fitted with one fly-wheel only and outside bearing suitable for electric-



lighting purposes. The vaporizing and igniting apparatus of this type is described in Chapter I. The fuel



Light-load diagram taken from Campbell engine: Cylinder, 9.5″ in diameter; stroke, 18″; revolutions per minute, 210; M. E. P., 55.9 lbs.



Full-load diagram from Campbell Engine: Cylinder, 9.5″ in diameter; 18″ stroke; revolutions per minute, 210; M. E. P., 69.25; compression pressure, 55 lbs.; maximum pressure, 232 lbs.

oil-tank is placed on the top of the cylinder and the

fuel is fed by gravitation to the vaporizer and to the heating lamp, there being no oil-pumps. There are only two valves—the air-inlet valve, which is automatic, and the exhaust-valve, which is operated by the cam, which is actuated by spur-gearing from the crank-shaft, the necessary power to open the valve being transmitted through the horizontal rod in compression. The centrifugal governor is mounted on separate horizontal shaft, and is actuated by separate gearing from the crank-shaft. The speed of the engine is controlled by suitable device which is inserted by the action of the governor between the exhaust-lever and the stationary bracket when the normal speed is exceeded, thus holding open the exhaust-valve and preventing any of the oil vapor and air from entering the cylinder during the suction period.

PRIESTMAN OIL ENGINE.

Fig. 74 represents this type of engine as made by Messrs. Priestman in the United States.

The design of this engine is upon the " straight line" principle, and differs from the other engines herein described. In this engine, both the fly-wheels are arranged to be inside of the main shaft bearings instead of at each side of the frame, as is usual. The makers claim great advantages for this design, inasmuch as the strain on the bearings is minimized. The crank-pin is placed between the two fly-wheels, the hub of each fly-

wheel becoming the cheek of the crank. The oil-tank is placed in the bed of the engine; an air pressure of five or six pounds is always maintained in this tank by means of the separate air-pump actuated from the cam-shaft by eccentric. The vaporizer spraying and igniting devices are fully described in Chapter I.

The governor is driven by belt from the crank-shaft

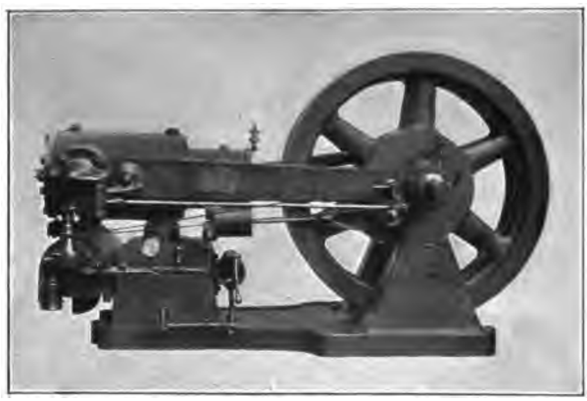
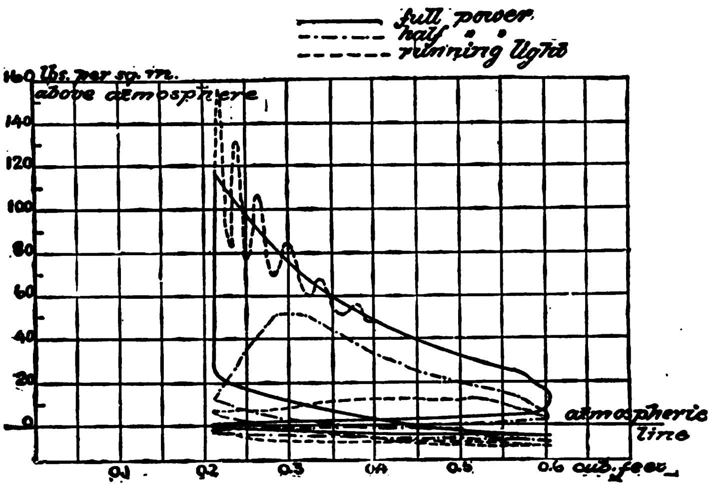


FIG. 74.

and is of the centrifugal or pendulum type. The speed of the engine is controlled by suitable mechanism acting on the throttle-valve regulating the supply of oil and air entering the vaporizer. The air-inlet valve to the cylinder is automatic, the exhaust-valve being actuated by horizontal rod operated from a cam placed

on the cam-shaft. This engine, it is claimed, requires little or no lubrication for the piston.

The following test was made in the Engineering Laboratory at University College, Nottingham, England, on single-acting horizontal English type of Priestman oil engine having cylinder $10\frac{3}{4}''$ dia. and



INDICATOR CARD OF THE PRIESTMAN ENGINE.

$14''$ stroke, capable of developing $10\frac{3}{4}$ actual or brake horsepower at 160 R. P. M. The test was made after seven years' service of the engine using American kerosene, known as Royal Daylight, specific gravity 0.792 at 60° Fahr. and having flash point 83° Fahr. The effective work recorded is the effective indicated

pressure in the cylinder, the back pressure of the exhaust and suction strokes being deducted.*

TABLE V.

TRIALS OF PRIESTMAN OIL ENGINE, DEC. 9, 1900 (ROBINSON).

Duration of run (hours)................—	2
Revolutions per min. mean...............—	160
Pressure before ignition (above atmosphere), lb. per sq. in.................—	20
Mean pressure, lb. per sq. in............—	44
Mean back pressure (pumping strokes) lb. per sq. inch......................—	3
Net effective pressure..................—	41
Net effective indicated H.P.............—	10.5
Brake or actual H. P....................—	8.4
Engine friction H. P....................—	2.1
Mechanical efficiency per cent..........—	80
Oil used per hour (total lb.)...........—	8.82
" " " " per I.H.P. lb......—	0.84
" " " " per B.H.P. lb......—	1.05
Cooling water through jacket, lb. per min.—	22.5
Cooling water rise in temp. 57° to 113° Fahr...........................—	56°

THE MIETZ & WEISS ENGINE.

This engine is illustrated in Fig. 75. It works not, as some other engines described herein, on the Beau de Rochas cycle, but on the two-cycle principle—that is, an explosion is obtained in the cylinder at each revolution of the crank-shaft. The oil-tank is placed above the cylinder, and fuel is supplied to the engine partly by gravitation—the quantity in-

*"Gas and Petroleum Engines," by Prof. Wm. Robinson, pp. 688.

jected, however, into the cylinder being regulated by small oil-supply pump. The governor is of the inertia type, and acts directly on the pump on the hit-and-miss principle in the Mietz & Weiss engines which were formerly made. If the speed of the engine exceeds the

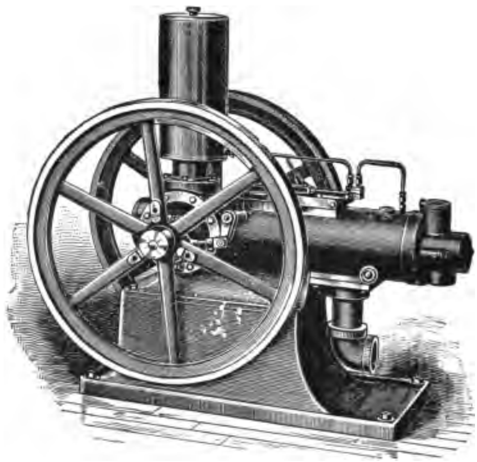


FIG. 75.

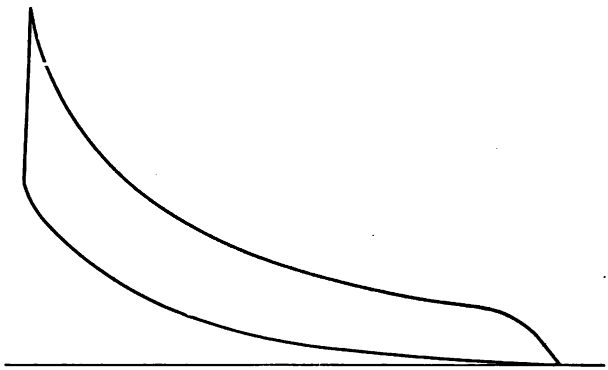
standard number of revolutions, the governor causes the charge of oil which otherwise would enter the combustion chamber or cylinder to be missed, and no explosion follows. The governor itself is actuated from the crank-shaft by eccentric and bell crank direct. The oil is vaporized in a hot chamber placed at the back of the cylinder, which is heated for a few minutes in starting by independent lamp; afterward the heat

created by constant compression maintains the igniter at proper temperature automatically.

The governor of the improved Mietz & Weiss engine is of the centrifugal type, and acts through a variable stroke on the kerosene pump, graduating the charge for varying loads. The governor weight is arranged near the shaft at the hub of the fly-wheel, to which it is pivoted at one end, the other end being secured to an adjustable spring, the tension of which determines the speed. The eccentric is free to slide at right angles to the shaft, and, being pivoted to the extreme end of the governor weight, receives a slight turning movement ahead from no load to full load. The regulation with this governor is extremely close in direct electric lighting service, where many of these engines are in use, either belted or direct-coupled to generators.

The deficiency of pressure in the crank-chamber is used to raise the lubricating oil from an oil well placed below the sight feed oilers which supply oil to the cylinder and crank-chamber. The crank bearings are lubricated by means of ring oilers. These engines are now made in various sizes from 1—60 H. P., being direct-connected to dynamos, as shown in Fig. 58*a*. They are also direct-connected to centrifugal pumps, hoists as well as air-compressors. The compression of the air is generated in the crank-chamber and the air is drawn into the cylinder at a slight pressure during each outstroke of the piston. The exhaust opening is automatically uncovered by the piston, the exhaust passage being made in the cylinder wall. As the

piston travels toward the end of the stroke, this passage is uncovered, and the products of combustion are free to pass to the exhaust-pipe, while the



Indicator diagram taken from the Mietz & Weiss Engine: diameter of cylinder, 12″; stroke, 12″; revolutions per minute, 300; scale, 100; B. H. P., 20.

piston travels to the end of the stroke and the first part of the return stroke until the port is again covered, when the compression period commences for the next explosion. Consequently no valves are necessary, the air inlet to the cylinder being controlled by the action of the piston only, which simplifies the action of the engine. Water is injected into the cylinder occasionally to facilitate lubrication of the piston; by this means the piston is cleaned and maintained free from deposit of carbon.

Hornsby-Akroyd Oil Engine.

Fig. 76 shows this engine as made by the De La Vergne Refrigerating Company, of New York. It is also made by the patentees at Grantham, England, and in France and Germany.

The Hornsby-Akroyd engine is made in sizes of 1½ to 500 H. P., all sizes being made of the horizontal type. The smaller sizes are made of the vertical type also, as shown at Fig. 77. The fuel oil-tank is placed in the base of the engine and the fuel is delivered to the vaporizer by the small pump actuated from the cam-shaft by the lever which also actuates the air-inlet valve. The oil supply is raised to the vaporizer valve-box in regular quantities, but the oil is only allowed to enter the vaporizer to the required amount, the remainder of the oil flowing back to the tank through the by-pass valve which is regulated by the governor. Thus, if the speed of the fly-wheel exceeds the normal number of revolutions for which the engine is set, the governor mechanism opens the by-pass oil-valve, allowing part of the oil to flow back to the oil-tank, and accordingly reduces the charge entering the vaporizer, and consequently the mean pressure for one or more explosions is reduced in the cylinder. The governor is of the Porter type, actuated by gearing from the cam-shaft. The method of vaporizing and igniting is fully described in Chapter I. Both air-inlet and exhaust

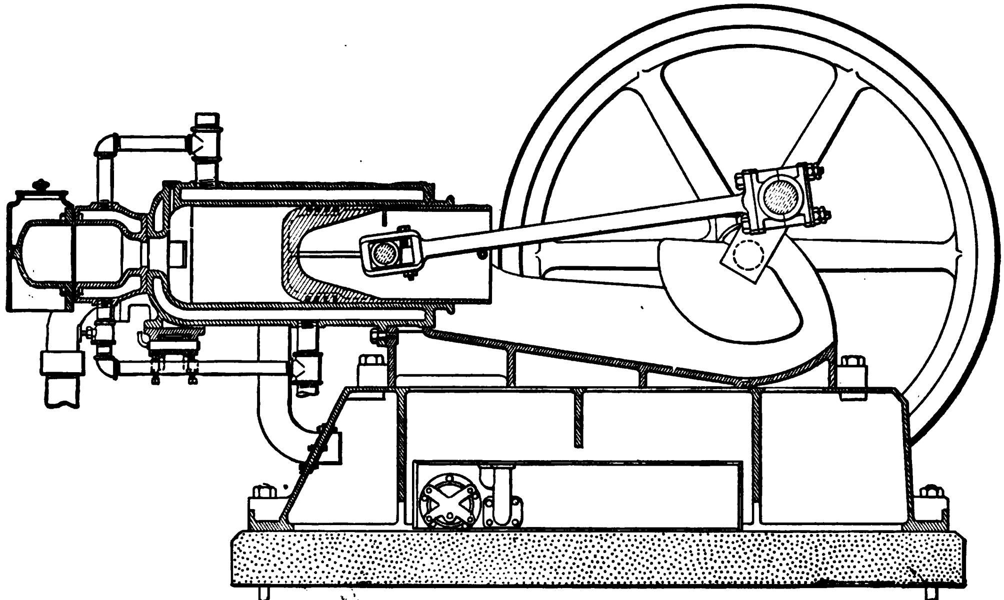


FIG. 76.

valves are actuated from the cam-shaft, these valves

FIG. 77.

being placed on the side of the engine. The air inlet in this type is different from the other engines de-

scribed. In this case the air enters not through the vaporizer, but by means of separate valve-chamber.

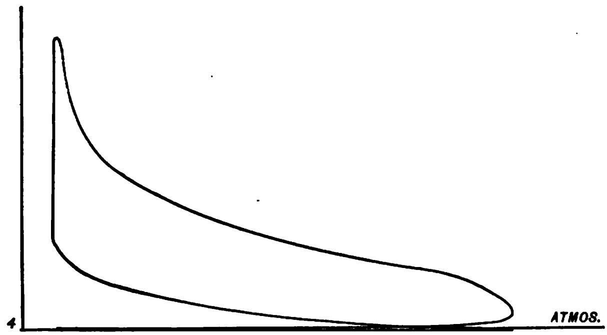


Diagram taken from Hornsby-Akroyd Engine: M. E. P., 48 lbs.; compression pressure, 50 lbs.; maximum pressure, 160 lbs.; revolutions per minute, 185; cylinder, 18.5″ diameter; 24″ stroke; full load.

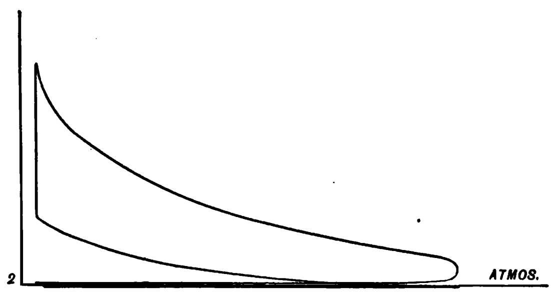


Diagram taken from Hornsby-Akroyd Engine: Diameter of cylinder, 11″; stroke, 15″; M. E. P., 49.5 lbs.; compression pressure, 60 lbs.; revolutions per minute, 230; consumption of oil W. W., 150° F. 0.8 lbs. per B. H. P. per hour.

TABLE VI.—TRIALS OF 25 B. H. P. HORNSBY-AKROYD OIL ENGINE, JAN. 4, 1898 (ROBINSON).

Power or Load Factor.	Full Load.	Two-thirds Load.	One-third Load.	No Load.	Maximum Load.
Duration of trial hours.....	3	3	2	1	¼
Revolutions per min. (mean)	202.6	202.4	203	201.5	203
Explosions per minute "	101.3	101.2	100	100.7	101.5
Mean effective pressure (net) lb. per sq. in.......	45.4–43.4	31.2	18.3	6	....
Indicated H. P.............	32.3–31	22.4	13.1	4.28	....
Brake or actual H. P........	26.74	17.96	9.0	0	39
Spent in engine friction, H. P.	5.56–4.26	4.44	4.1	4.28	....
Mechanical efficiency, per cent......	82.4–86	80	69	......	....
Oil Used in Engine.					
Per hour...............lbs.	19.75	16.75	12	5.75	....
" I. H. P., hour "	0.61–0.63	0.74	0.91	1.34	....
" B. H. P. " "	0.74	0.91	1.3	......	....
Jacket Water.					
Lb. per minute.............	67.5	......	60	......	....
Final temperature (Fahr.)..	138°	130°	132°	142°	138°
Rise in degrees " ..	47°	29°	29°	32°	26°
Equivalent H. P. lost.......	74.8	......	41	......	....
Indicated Pressure lb. per sq. in. above Atmosphere.					
Compression before ignition	60	60	50	55 to 75	....
Explosion pressure.........	168	150	95	......	....
Percentage equivalent of effective heat from oil..					
Useful work at Brake......	18	......	10	......	....
Spent in engine friction...	3	......	4.5	......	....
Shown on indicator diagram	21	......	14.5	......	....
Carried away in jacket water	50	......	45.5	......	....
Balance lost in exhaust gases and unaccounted for....................	29	......	40	......	....

The day was rainy, with mist and complete saturation of air. The engine was cold when lamp lighted at 10.15 A.M., and started working in five minutes. Observations were made in full load trial at 10.30 A.M.

From "Gas and Petroleum Engines," by Prof. Wm. Robinson, page 710.

The vertical type Hornsby-Akroyd engine, which has been referred to on page 117, is also shown here in section (Figs. 78 and 79). The cam-shaft is operated

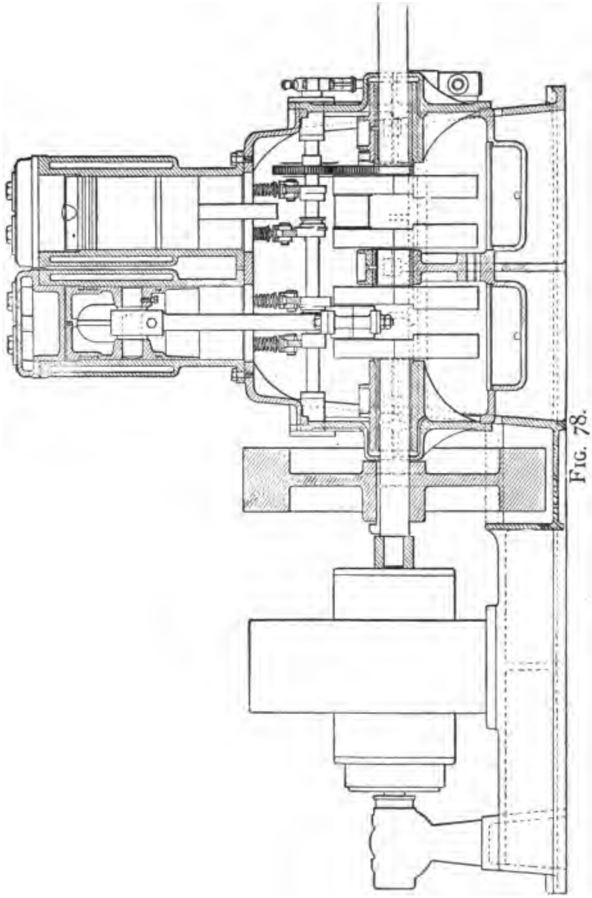


FIG. 78.

by a gearing from the crank-shaft in the regular way, the valves being operated by levers and rods. As will be seen from the illustration, the cylinders are built separately, being water-jacketed and mounted on a

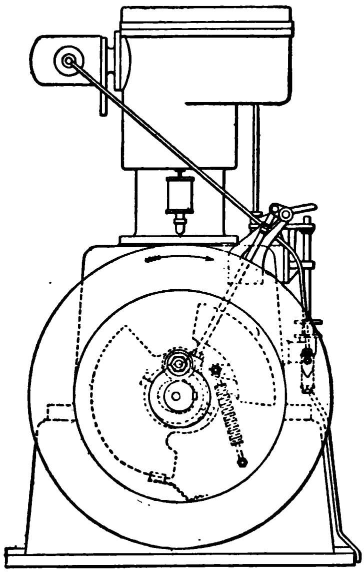


FIG. 79.

cast-iron frame of the enclosed type containing the crank-shaft. Lubrication is effected from the splashing of the crank in a bath of oil. The 15 H. P. engine has cylinders $8\frac{1}{2}''$ diameter by $9''$ stroke. The governing is effected by regulating the length of the stroke of the oil pump; no adjustment of the pump is therefore necessary. The governor is of the Rites pat-

ent type, and a regulation of less than 2 per cent is claimed by the makers of this engine, with a variation of the load within the engine's limits.

The Rites Governor.

An illustration of the Rites governor is shown at Fig. 80. It will be seen that it is placed in the fly-

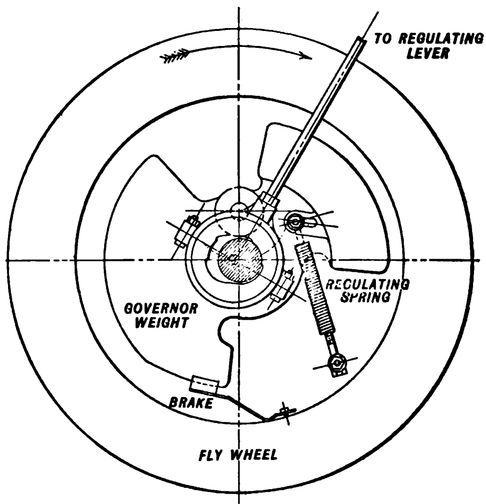


Fig. 80.

wheel in the usual way with this type of governor. The Rites governor has now become so widely known that only a short description is necessary. Briefly, it consists of but a single weight, distributed on opposite sides of the shaft with a spring connection to balance centrifugal force. In its application to the oil or gas

engine an eccentric cast in one piece with the weight structure is provided. The movement (while in operation) of the governor weight consequent upon any change in speed of the crank-shaft is transmitted to the regulating device by means of the eccentric attached to the governor weight, on which are fitted eccentric straps and rod. The other end of this eccentric rod is attached to a lever, which reciprocates the shaft on which is placed the eccentric fulcrum controlling the stroke of the plunger of the oil-supply pump or the opening of the gas valve.

The operation is as follows: If the speed of the crank-shaft is increased by a fraction beyond the required maximum speed, the momentum of the weight overcomes the strength of the spring, thus changing the throw of the eccentrics, which in turn reduces the length of the oil-pump stroke.

Among the many claims for the Rites governor are the following: It allows of a large range of adjustment. It is remarkably quick in action, and the distribution of the governor weights on each side of the weight-pin and also on each side of the crank-shaft allows the governor strength to be greatly increased without necessarily increasing the centrifugal element correspondingly, and utilizes the inertia action of the governor most effectively for extreme changes of load. There is only one bearing requiring lubrication—namely, that of the fulcrum pin. No dash-pot is required, and only a small brake or drag is used to steady the movement of the governor weight.

The speed of the engine is altered by the adjustment

of the spiral spring controlling the weights. Speed is increased by moving the pin holding spring outwards from the fulcrum pin and at the same time correspondingly increasing the tension of the spring, to preserve a constant proportional initial tension corresponding to the change of leverage of the spring.

To decrease speed, reverse the above operation, or, if desired, add to the weight, thus increasing its centrifugal force.

To remedy racing, move the spring connection to the governor weight in its slot *away* from the weight-pin, leaving the tension of the spring unchanged. If it is required to regulate closer, reverse this movement of the pin in its slot; that is, *towards* the weight-pin.

To remedy sluggishness of the governor examine the bearings and other parts of the governor; such action is due to excessive friction, which in turn will probably be on account of failure in lubrication of the pin.

THE BRITANNIA CO.'S OIL ENGINE.

An engine fully described in the *Engineer** (London), made by the Britannia Co., of Colchester, England, is shown at Figs. 81, 82 and 83. It will be seen from the illustrations that it is of simple design. The vaporizer is a modification of the type as shown at Fig. 2 and referred to on page 8. The oil is stored in the base of the engine and is raised to the vaporizer by the suction of the piston. Consequently no oil pump is required. The air inlet valve *C* is automatic,

*See *Engineer* and *Engineering*, London, of June, 19, 1903.

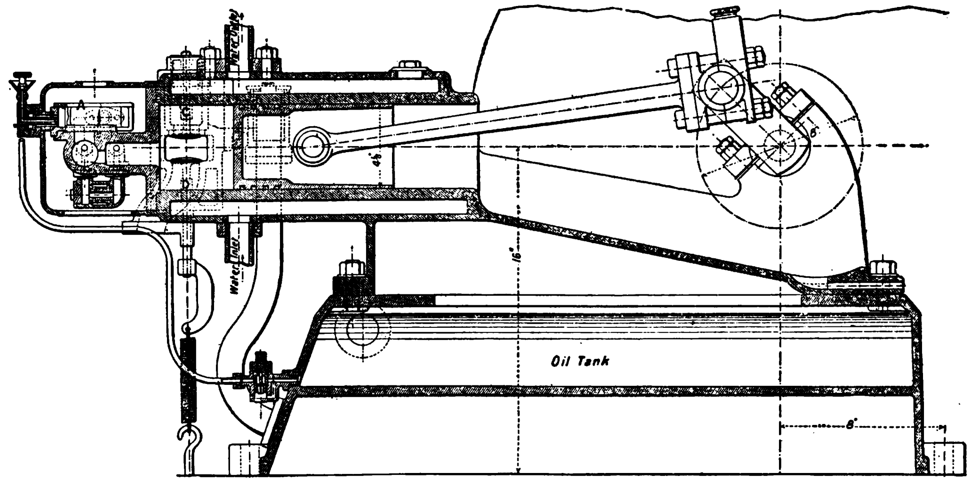


FIG. 81.

and is placed on the side of the engine above the exhaust valve *D*. The governor is of the centrifugal type and operates on the "hit-and-miss" principle, and is arranged to control the vapor inlet valve. On starting the engine the vaporizer is heated by external lamp for a few minutes and a small amount of fuel is injected into the vaporizer by means of the filling cup, marked *E*. The vaporizer consists of a flat cast-iron box, marked *A*, provided with baffle plates, which cause the oil or vapor to travel backwards and forwards

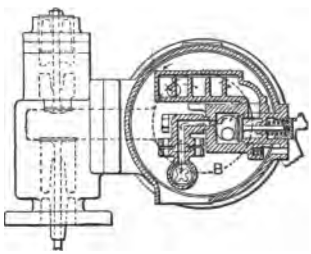


FIG. 82.

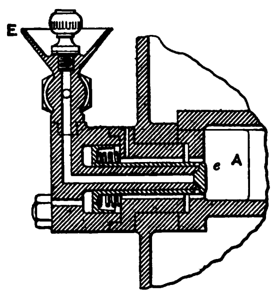


FIG. 83.

through passages before entering the cylinder. The ignition is caused by means of tube *B*.

In operation the oil is raised to the vaporizer from the tank by the vacuum in the cylinder, caused by the outstroke of the piston. The cylinder communicates with the vaporizer through the vapor inlet valve only. Air enters both through the main air inlet valve *C*, Fig. 81, and a passage communicating with the vaporizer. The air entering can be throttled so that proportions of air entering by alternative ways can be regulated

as required. The oil supply enters by the passage closed by means of sleeve *e*, which forms also a valve as shown in Fig. 83. When the sleeve moves, due to the vacuum in the cylinder, by piston movement, oil is drawn (through holes in the sleeve) into the vaporizer. The amount of oil entering depends on the amount of air allowed to enter the cylinder through the vaporizer. When due to the action of the governor, the vapor valve remains closed, no communication is made with the cylinder and no oil enters the vaporizer. Two passages between the vaporizer valve and the cylinder are made, in one of which is the igniter-plug, which is simply a piece of steel having projecting internal ribs which absorb the heat from explosion, becoming red-hot in operation. No exhaust gases pass through the igniter, and on light loads gases only enter the igniter preceding an explosion. The temperature of igniter and vaporizer is easily maintained, and no stoppage due to the cooling of the vaporizer can occur.

INTERNATIONAL POWER CO.'S ENGINE.

A vertical type oil engine, more particularly designed for use in launches, and also in automobiles, is shown at Figs. 84 and 85. It is of the two-cycle type, the compression of the air previous to ignition being effected in the crank chamber, from whence it passes by a passage and port uncovered by the piston as it moves forward to the cylinder. The oil is supplied by gravity, or from a tank under pressure provided with a small air-pump operated by hand. The supply is regu-

lated by a butterfly valve inserted in the air passage entering the cylinder. From the accompanying sec-

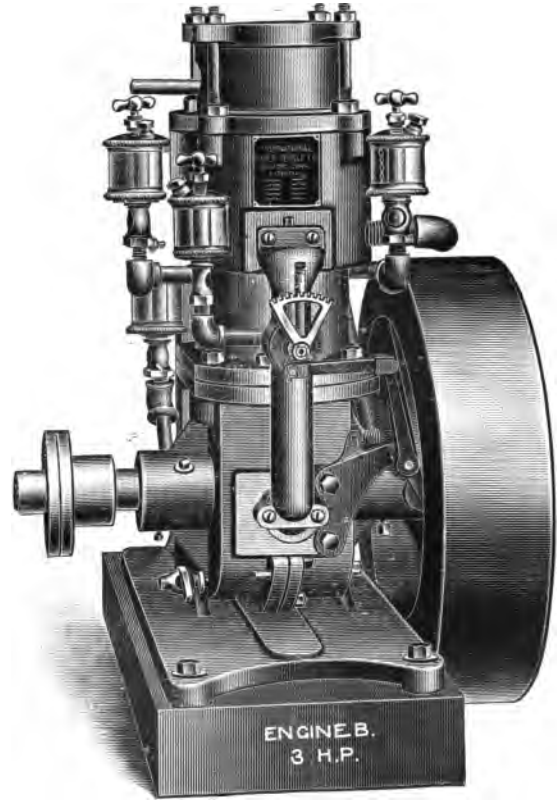


FIG. 84.

tional view of the engine it will be seen that the unique feature of this type of engine is the design of the cyl-

inder and piston. The upper part of the cylinder is of reduced diameter, and the upper part of the piston is suitably designed to enter this smaller chamber.

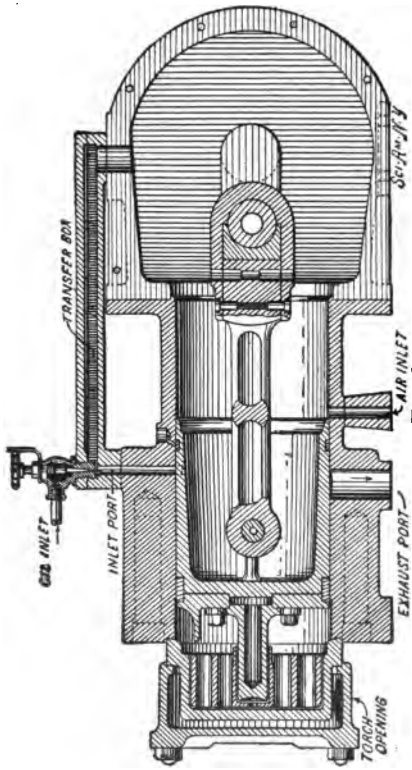


FIG. 85.

The oil vapor and air enter the cylinder, part of which is compressed to a very high pressure in the auxiliary or smaller cylinder. The piston enters this smaller

cylinder after the main piston has traversed about half its stroke. The high compression in the small diameter cylinder is sufficient to ignite the gases, and by means of the passages at the top of the small cylinder the flame passes to the gases compressed to a lower pressure in the main cylinder. This engine is made by the International Power Vehicle Co., of Stamford, Conn.

The Barker Engine.

A type of engine which in recent years has received some attention from inventors is that in which the cylinders revolve around a fixed crank-pin or cam. For situations where space is limited and where vibration should be eliminated and weight per horse power re-

Fig. 86.

duced to a minimum, the advantages of this type of engine are apparent.

Fig. 86 shows the engine complete. It will be noted that there is no fly-wheel, the cylinders themselves

revolving around the centre bearing and furnishing the necessary momentum. The engine works on the "Otto," or four-cycle; that is, each cycle of operation in each cylinder consists of four strokes; thus a four-cylinder engine has four impulses each revolution. This is effected by the use of the cam motion shown in Fig.

FIG. 87.

FIG. 88.

87, instead of the ordinary crank. This mechanism is equivalent to a double-throw crank.

Fig. 88 shows the four pistons in position, the cylinders having been removed.

The air and vapor inlet to the cylinders and the exhaust outlet are effected through the hollow spindle on which the cylinders revolve, radial ports or passage-ways being made in the spindle, which are uncovered by recesses in the cylinders, as these recesses coincide with the ports of the cylinder at each revolution.

The ignition is caused by electric igniter of the jump-spark type. The timing of the ignition is obtained by

a revolving contact breaker. When using gasoline, a carburetor of the ordinary float type is attached. When kerosene is used as fuel, a vaporizer somewhat similar to that shown at Fig. 3 is used, the heat from the exhaust gases being sufficient to maintain the required temperature for vaporization. The oil is fed by gravity and the vapor is drawn into the cylinder by the piston displacement in the usual way. The power is taken off from a pulley attached to the sides of the cylinder.

A motor of this type of one actual horse-power weighs about 15 lbs.; a 3 H. P. weighs approximately 35 pounds. A speed of about 800 R. P. M. is obtained, which speed is varied by the lead given to the igniter. When running at a high speed the engine can be held in the hands without vibration.

CHAPTER XI.

PORTABLE ENGINES.

PORTABLE type oil engines, made by nearly all makers of fixed horizontal engines, are used for various purposes. Such engines combined with air compressors are very useful for operating pneumatic tools used in structural iron work, repairs and similar work where compressed air is required in different locations for short periods of time. For portable electric-lighting purposes the oil engine (Fig. 89) is well adapted. Electric lighting outfits of this kind have been found useful for operating search-lights for military purposes and for supplying current for electric lighting for contractors, etc., where illumination of a portable nature is required for a short period only. The portable oil engine is also largely used for farm work, such as operating threshing machines, etc.

In all cases these engines are required to be frequently removed from place to place, and therefore must be as light as possible in design, but must be of such substantial construction that they can be transported from place to place over rough, uneven roads, and all provision for operation in the open air must be made. In Europe the portable engine is generally constructed somewhat differently to the ordinary fixed

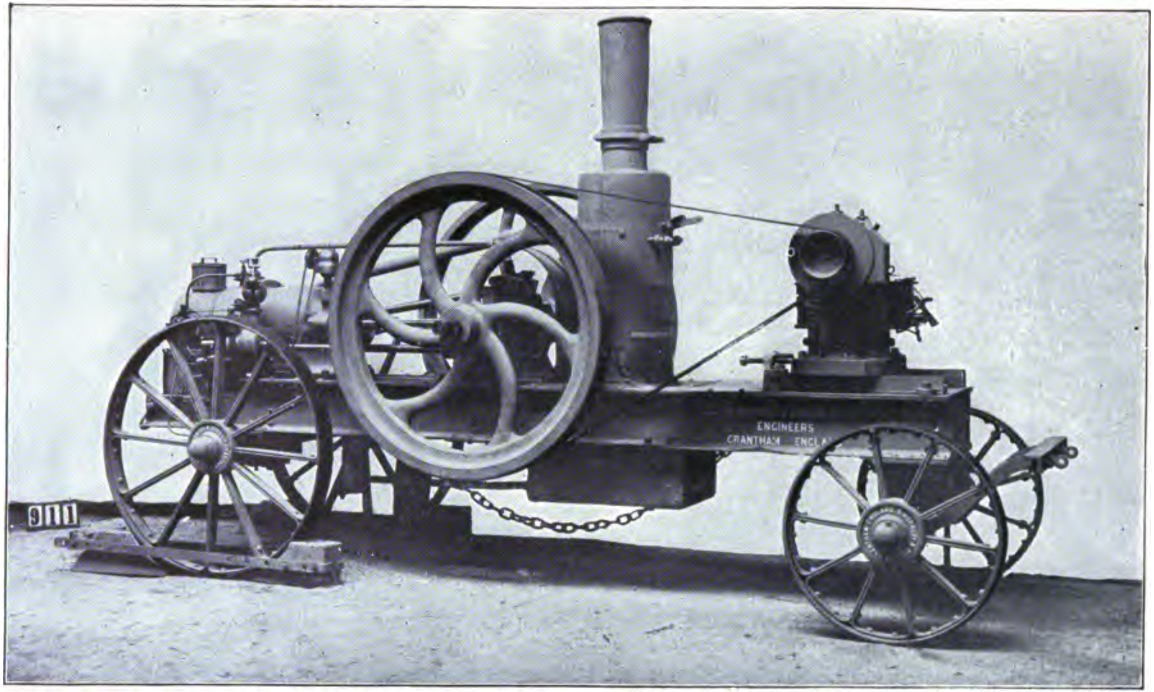


FIG. 89.

(To face p. 200.)

engine. The heavy cast-iron bed-plate used in fixed engines is replaced with light steel construction, which considerably reduces the weight. This type of construction is shown in Fig. 89, and while it is somewhat more expensive than those portable engines composed of the fixed engine without base-plate bolted to steel or wooden truck, the advantage of lightness is gained as well as facility in transportation.

In the United States the portable engines are more generally composed of the standard fixed engine placed on steel or timber truck. This outfit is cheaper in cost than that of the special construction above mentioned.

The portable engine is often required to operate in localities where running water is not available, and therefore it must be self-contained as regards the cooling of the cylinder. An important feature of this outfit is, therefore, the cooling-water apparatus. In order that only a small amount of water may be used, different devices have been constructed for rapidly cooling a small amount of water. Such device in the Hornsby-Akroyd consists of a gradirwork placed inside the circular chamber, seen in Fig. 89, placed in the front of the engine. The water is circulated around the cylinder of the engine by a small reciprocating pump operated from the cam-shaft, and after passing through the cylinder and taking up the heat is delivered to the upper part of this chamber and flows down a wooden gradirwork. A draft of air is at the same time induced by the exhaust emitted above, which

rapidly cools the water as it trickles down the slats of the gradirwork. For a 20 H. P. engine only about 30 to 40 gallons of water are required.

Another device for cooling the water is that composed of trays over which the water flows while a

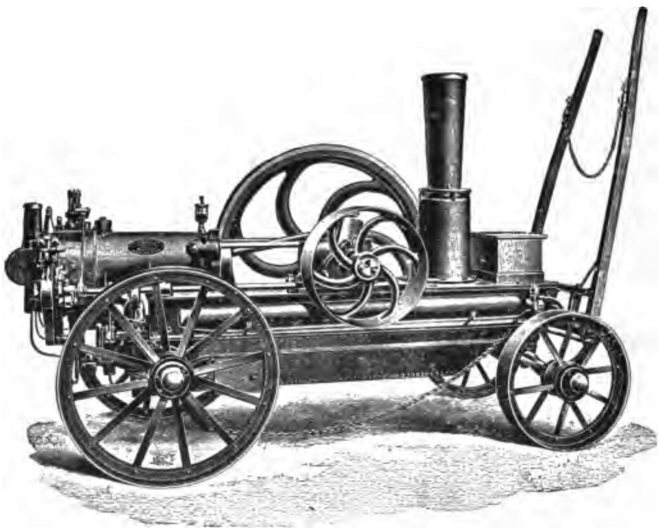


FIG. 90.

draft of air is induced in the same way as above mentioned.

An engine equipped with this cooling device is shown in Fig. 90, as made by Crossley Bros., Manchester, England.

Another type of portable engine is that shown in Fig. 91, consisting of the Mietz & Weiss engine. This

is the standard fixed engine placed on a truck, the cooling water being supplied from a tank in front of the engine.

As the internal combustion engine cannot be balanced as effectually as the steam engine, greater vibration of the engine has to be overcome in holding it in

FIG. 91.

place. An important feature of the portable engine, therefore, is the chocking device which is required to hold it rigidly in position when in operation. In some engines simply a wooden chock is used, placed each side of the wheel and drawn together, holding the wheels from moving. A very effective device is that composed of four adjustable struts, each having turnbuckle fitting

into a flat timber plank placed on the ground lengthwise under the engine and protruding from each end. When it is desired to hold the engine in position,

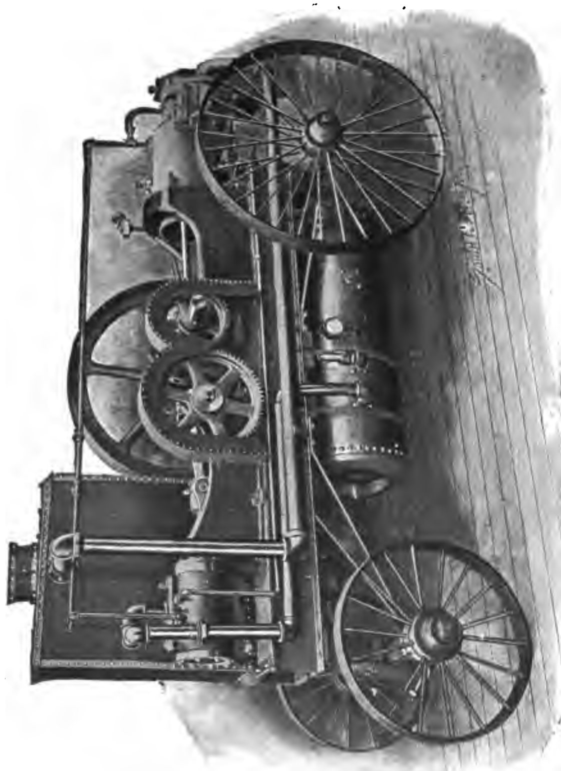


FIG. 92.

the struts, placed at each end of truck, are lengthened by means of the turnbuckle, thus taking the

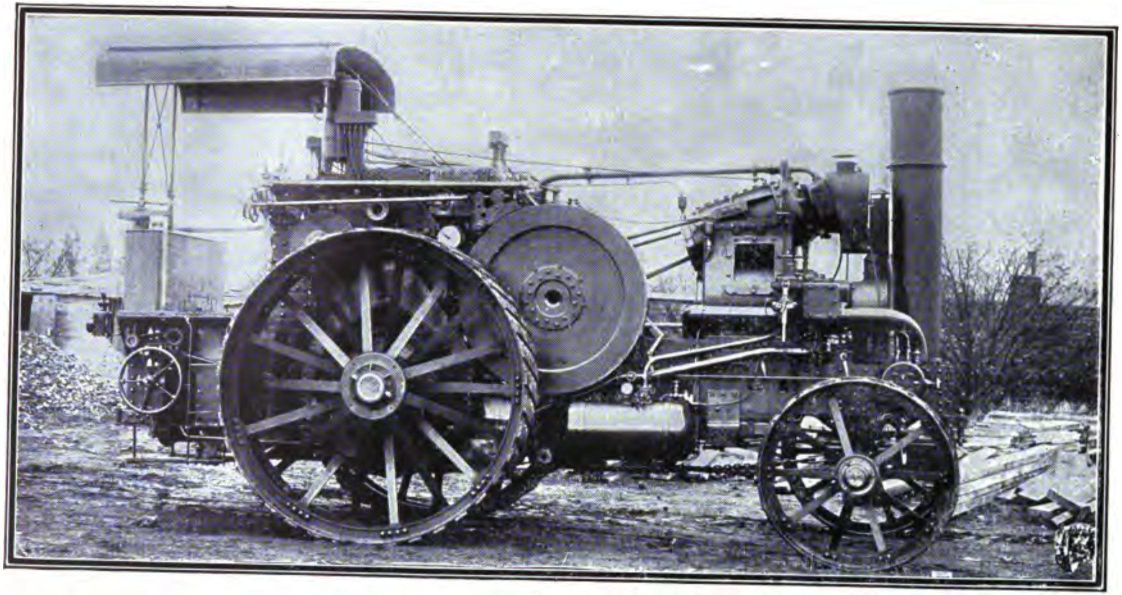


FIG. 92a.

(To face p. 204.)

weight off the wheels. By this means the engine is held as rigidly as when on a concrete foundation, and without movement. When it is required to remove the engine the struts are shortened by simply unscrewing until the weight is taken up by the wheels. The wear on the wheels due to the continuous vibration of the engine is thus avoided, and the wheels can consequently be lighter in construction.

A portable air-compressing outfit is shown in Fig. 92. As will be seen from the illustration, it is composed of the oil engine, which operates the air-compressor by a gearing, the air receiver being placed beneath the frame of the truck, while the cooling-water device is placed lengthwise with the air compressor.

An oil traction engine is shown at Figure 92*a*, in which the ordinary frame and truck of the steam traction engine is used, the boiler being replaced by an oil engine.

The engine shown in the illustration has two cylinders placed at an angle to each other, the connecting rods operating on one crank-pin, the power from the crank-shaft being transmitted by gearing to the road-wheels. The cooling of the water is effected somewhat similarly as with the portable engine. This type of engine, made by Messrs. R. Hornsby & Sons, Grantham, England, after very severe tests recently received a first prize of £1,000 from the British War Department.

CHAPTER XII.

LARGE-SIZED ENGINES.

THE higher thermal efficiency of the gas engine as compared with that of the steam engine and its adaptability to use the poorer and cheaply produced gases made in the producer plant, the Mond gas plant, as well as the gases given off from blast furnaces, etc., has resulted in its development and manufacture in units as high as 5000 H. P.

The "oil gas" producer, an apparatus for furnishing gas produced from vegetable and mineral oils, is also used in connection with the gas engine; and also, as described hereafter, the apparatus developed by C. C. Moore & Co., of San Francisco, for generating gas from crude oil, which gases are furnished to the gas engine. Until recently the oil engine self-contained, that is, requiring no outside gas-making apparatus, of 100 H. P. was probably the largest unit made. The oil engine up to 500 H. P. is now, however, being manufactured.

The production of great quantities of petroleum in Texas and California chiefly useful for fuel purposes only, and which can be procured at a low price as compared with illuminating oils, has enabled the oil engine in many locations to compete in cost of installation and

operation with gas engines using producer and other cheap gas.

With the smaller size oil engines simplicity of construction is probably the most important feature, as it must be adapted for successful operation in the hands of unskilled attendants and be free from all delicate mechanisms which may require skilled attention. With the larger size engines, which have a greater earning capacity and which allow of the expense of a skilled attendant, simplicity of construction is not so important a feature. Mechanisms which may frequently give trouble in the smaller engines when in the hands of unskilled and inexperienced attendants may in the hands of the engineer attending to the larger engines give continuous satisfaction.

The tendency in design of the larger size gas engines is resorting to the two-cycle method of operation. Where the four-cycle method is adhered to two or more cylinders are employed. The four-cycle single-cylinder engine, as already explained in Chapter I., obtains an impulse once in two revolutions, and consequently during the three idle strokes of the piston the power and speed must be maintained by the momentum of the fly-wheels, necessarily enormous in an engine of 100 H. P. or over for the power obtained, in comparison with the fly-wheel of a steam engine of the same capacity. With the two-cycle engine, in which an impulse is obtained each revolution of the crank-shaft, double the power is developed as compared with the four-cycle engine of the same size. The mechanical efficiency is increased, owing to the reduced

weight of the fly-wheels, and the weight and cost of the engine per H. P. is curtailed.

The difficulty of procuring proper combustion in the two-cycle oil engine, more essential where crude oil is used than where gas or gasoline is the fuel, is not yet entirely overcome.

It has been previously stated that the larger size oil engines, to compete with the gas engine in cost of fuel, can do so only when a cheap grade of oil is used as fuel. To use such fuel, it is imperative that proper combustion takes place in the cylinder.

It is of interest to compare the relative cost of operation of the steam engine, the gas engine and the oil engine of, say, 50, 100 and 200 H. P. As the cost of fuel varies in different localities according to the cost of transportation, etc., this cannot be done to suit all cases. The following table, however, shows the relative cost of installing and operating a steam, gas and oil engine plant of 50 to 200 H. P. The cost of the plant includes cost of land, building of engine and boiler house, foundations, smoke-stack, etc., and all auxiliary apparatus. The cost of producer plant, and the cost of oil storage tanks and cost of apparatus for handling fuel is also included. It will be noted that the cost of water supply has in each instance been neglected. This is done because the amount of water required would be approximately the same with each type; possibly a saving in favor of the oil and gas engine would in many installations be effected. The figures must be modified to suit the actual cost of fuel in a locality differing from those given. The saving favorable to the gas-engine

TABLE VII.—RELATIVE COST OF INSTALLING AND OPERATING POWER PLANTS BURNING DIFFERENT FUELS.

Basis for Calculations: 300—10 hour working days per year. Coal at $3.00 per 2000 lbs., or 0.15 cent per lb. Illuminating gas at 80 cents per 1000 cubic feet. Crude Oil at 3.5 cents per gallon of 7.5 lbs., or 0.4⅔ cent per lb.

Brake Horsepower.	50			100			200		
Type of Engine Used.	Steam Automatic Non-Condensing.	Illuminating-Gas Engine	Oil Engine.	Steam. Automatic Condensing.	Producer-Gas Engine.	Oil Engine.	Steam. Compound Condensing.	Producer-Gas Engine.	Oil Engine.
Cost of plant complete, with machinery, foundations, building and land, per H.P., $	160	130	135	145	150	120	120	132	102
Fixed charges, 16%* per H.P., $	25.60	20.80	21.60	23.20	24.00	19.20	19.20	21.12	16.32
Fuel per H. P. per hour......	7 lbs. coal	20 cu. ft.	0.9 lb.	6 lbs. coal	1.5 lb. coal	0.9 lb.	4 lbs. coal	1.25 lbs. coal	0.9 lb.
cents	1.05	1.60	0.42	0.90	0.225	0.42	0.60	0.1875	0.42
Fuel per H. P. per year.	21,000 lbs.	60,000 cu. ft.	2,700 lbs.	18,000 lbs.	4,500 lbs.	2,700 lbs.	12,000 lbs.	3,750 lbs.	2,700 lbs.
$	31.50	48.00	12.60	27.00	6.75	12.60	18.00	5.63	12.60
Oil, waste, supplies per H.P. per year ....$	2.70	3.50	3.50	2.40	3.30	3.30	2.00	3.00	3.00
Cost of attendance per H. P. per year................$	18.00	5.00	5.00	10.00	7.50	5.00	10.50	8.00	5.00
Cost of one B.H.P. per year, $	77.80	77.30	42.70	62.60	41.55	40.10	49.70	37.75	36.92
Cost of one B. H. P. per hour................cents	2.593	2.577	1.423	2.087	1.385	1.337	1.643	1.258	1.231

The fuel consumption here allowed includes *all* the fuel used in a plant. It is based on the actual H. P. delivered, and represents average values as obtained under ordinary conditions of working.

* Fixed charges include: Interest on investment, 6%; depreciation and maintenance of machinery, 6%; building, 2%; insurance and taxes, 2%.

installation due to the recovery of by-products which is effected with the Mond gas plant is neglected, and should be taken account of where this system can be

FIG. 93.

used. The steam turbine, it will be noted, is not mentioned in this classification, the steam engine considered being the reciprocating type.

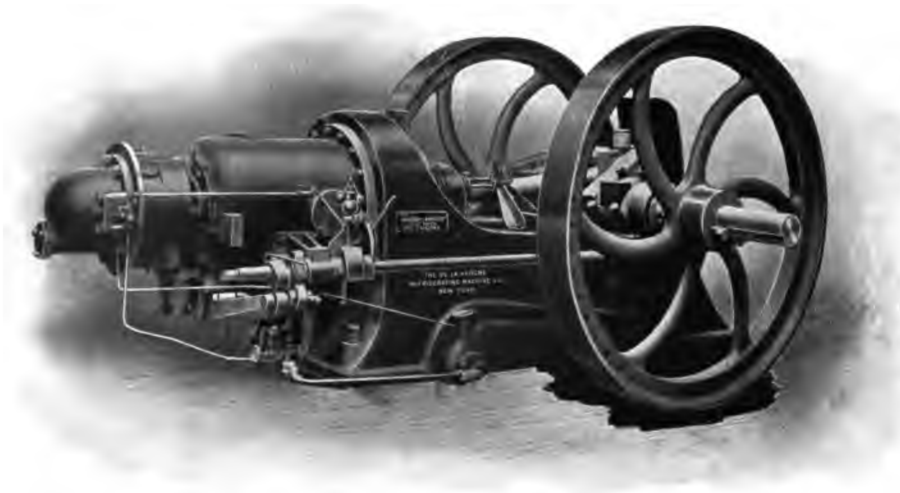


FIG. 94.

(To face p. 210.)

THE MIETZ & WEISS two-cycle oil engine has already been described. An engine of this type of 60 H. P. is shown at Fig. 93. It will be seen that it consists of two smaller engines coupled together and placed on one base-plate. Each engine is self-contained and, if necessary, can be operated alone by simply uncoupling the connecting-rod, etc.

THE HORNSBY-AKROYD engine of 125 H. P. is shown in Fig. 94. This engine operates on the four-cycle system. Its proportions are necessarily large as compared with the two-cycle type, and, owing to the three idle strokes present when the Otto cycle is used, the fly-wheels must be very heavy to obtain even running. The advantage, however, is gained of obtaining a good combustion, which is not always the case with the two-cycle engine, and consequently crude oil can be satisfactorily consumed in this engine. The deposit of carbon when using crude oil is abstracted from the vaporizer through the hole in the back of that chamber shown in the illustration, and which is covered by a flange. These engines are now made up to 500 H. P. by R. Hornsby & Sons, Grantham, England.

A sectional view of the cylinder is shown at Fig. 95, in which will be noted the water-jacketed piston and the method of supplying the water to it. In other respects this engine operates in a similar method to the smaller sizes already described. They are started by compressed air supplied from a reservoir, the air entering the cylinder by means of valves and valve-box connected to the reservoir already described on page 105. In the larger engines water-jacketing of the pis-

ton is required in addition to the water-jacketing of the cylinder to preserve the proper temperature necessary for lubrication, and to prevent undue expansion of the piston being exposed to the greater volume of gases in the cylinder. The water is introduced by a sliding tube to the piston, with which it reciprocates.

THE DIESEL ENGINE.

The Diesel engines are built by the American Diesel Engine Co., at Providence, R. I. They are also built by several manufacturers in Europe, both in Great Britain and Germany. The Diesel engine, as at present made in the U. S. A., is shown at Fig. 96. The engine here described is the type built by the makers under American and Canadian patents.

The chief characteristic of the Diesel engine is the high thermal efficiency obtained and the consequent low consumption of fuel. The high thermal efficiency, which it is claimed is 38%, is due to the high compression of the air in the cylinder, to the exceedingly small clearance in the cylinder, which is approximately 7% only of the total cylinder volume, and to the slow combustion of the fuel which is effected by the method of injecting the fuel peculiar to the Diesel engine.

As will be seen from the accompanying illustrations, this engine is of the vertical type and is of very substantial construction. The cylinder walls, cylinder head and valve chambers are water-jacketed. The enclosed crank-chamber is advantageously made readily

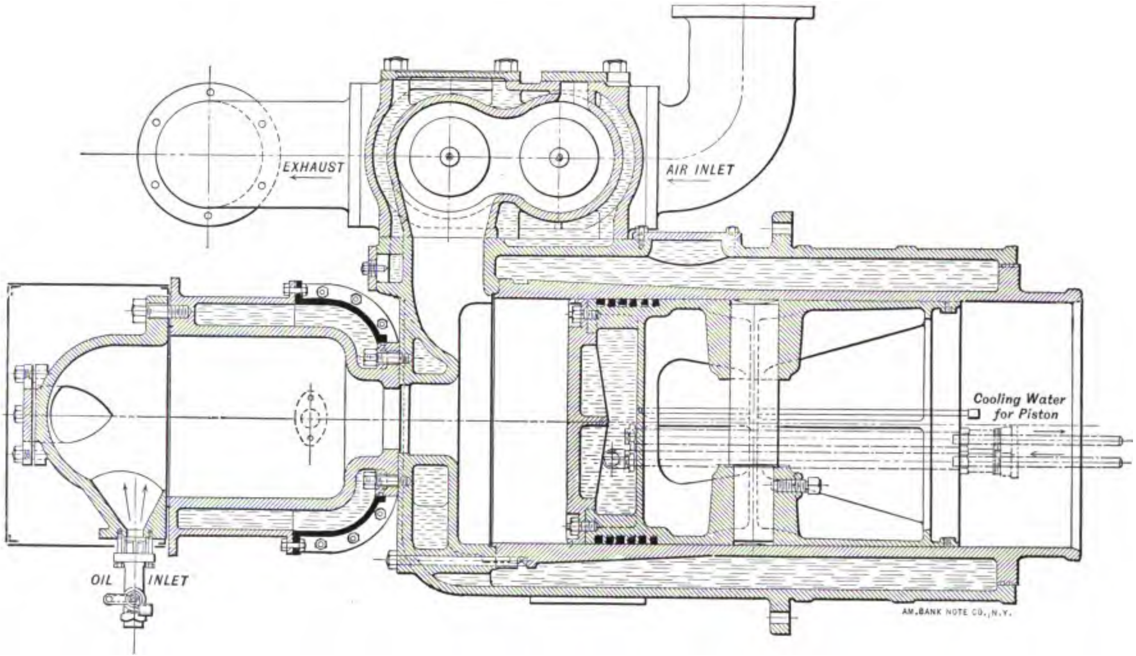


FIG. 95.

(To face p. 212.)

accessible by means of removable plates on either side of it.

Fig. 97 shows in plan and partly in section the Diesel engine of the three-cylinder type. It is also made with single and double cylinder.

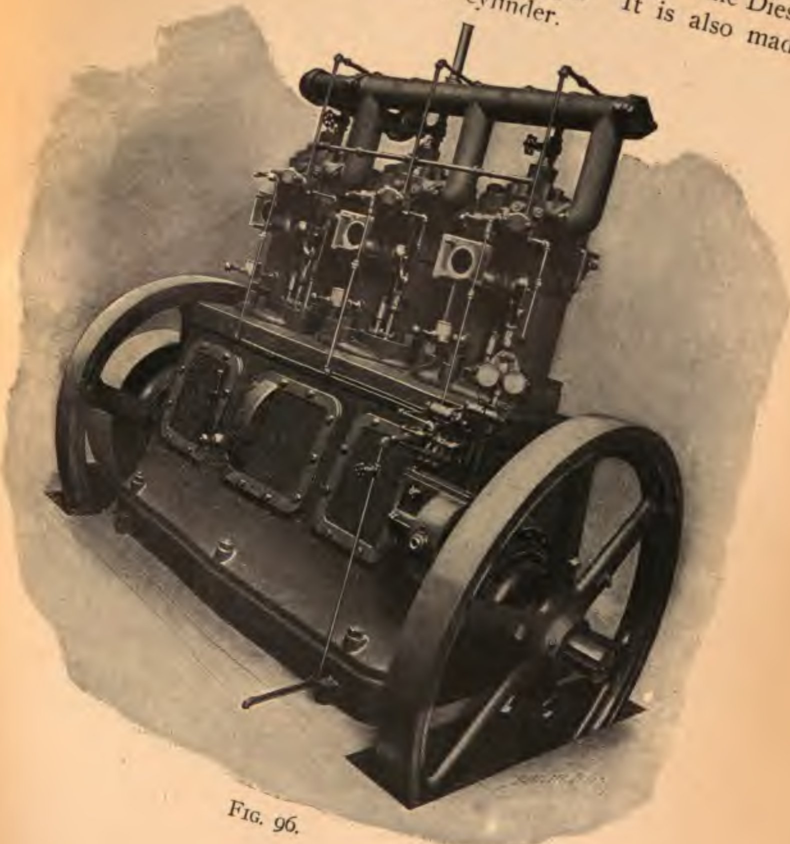


Fig. 96.

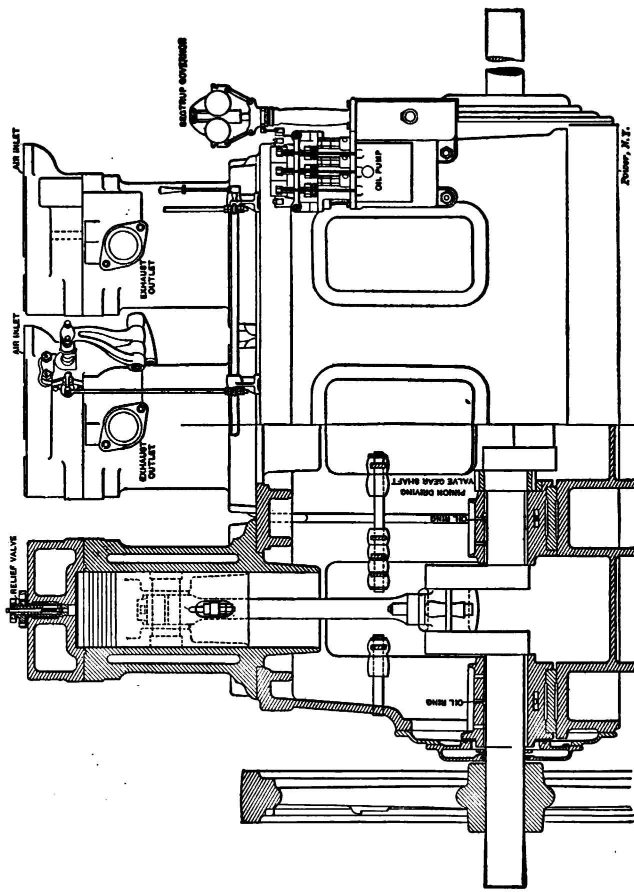


FIG. 97.

A sectional end view is shown at Fig. 98. The crank-shaft, or main bearings, are adjustable by means

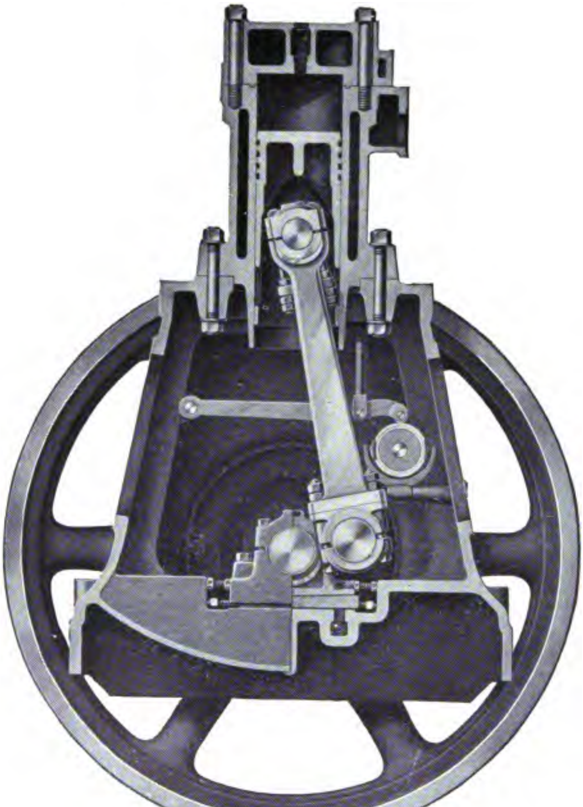


FIG. 98.

(To face p. 214.)

of wedges and screws, as shown. The piston is made as long as possible, in order to give a maximum bearing surface, and is fitted with steel snap-rings. The connecting-rods are of the marine type, with adjustable bearings at both ends. The valve motions are operated from the cam-shaft inside the enclosed frame, which is actuated by gearing from the crank-shaft. The engine operates on the "Otto," or four-cycle, principle. The air supply for supporting combustion is drawn into the cylinders through the air inlet valves placed in the housings to one side of the top of the cylinder head. (See Fig. 99.) The fuel to the cylinders is supplied by a separate oil pump for each cylinder. The oil pump is operated from a shaft geared to the cam-shaft. The method of operation is as follows:

The engine is first started by means of compressed air, which is supplied from an auxiliary air receiver suitably connected to the cylinder by means of a starting valve operated by a starting cam, thrown into action by hand, before starting. By this means compressed air is admitted to the cylinder and the piston is moved forward for one or two revolutions. Simultaneously compression of the air in the other cylinders takes place, which is sufficient to ignite the charge of oil in them. As soon as the ignitions take place the starting cam is automatically thrown out of action, the exhaust cam being simultaneously thrown into action. The admission valve for fuel and air under pressure is shown in Fig. 99. As will be seen, the valve spindle is surrounded by a series of brass washers perforated with small holes, being parallel to the

spindle. The fuel before entering the cylinder occupies the cavities in and between these washers as it is delivered from the fuel pump. Compressed air is introduced behind the oil inlet and at the opening of the

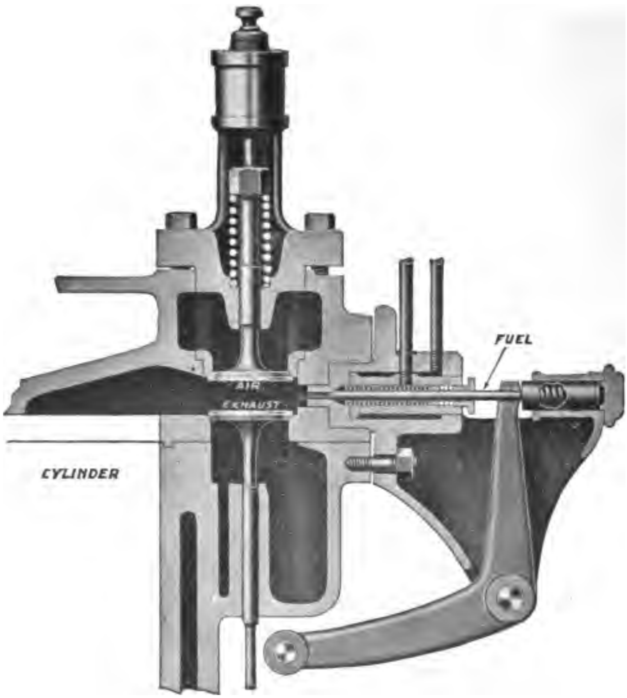


FIG. 99.

admission valve the oil is sprayed into the cylinder. The fuel enters the cylinder only after the compression stroke is completed and when the piston is beginning

to descend. The compression in the cylinder caused by the previous up-stroke of the piston reaches a pressure of 450 to 525 lbs. per square inch; resulting temperature approaches 1000° Fahr., which is more than sufficient to ignite the oil vapor. The fuel valve remains open about one-tenth of the period of the expansion stroke. The amount of fuel entering depends upon the action of the governor. Air in excess of that required to burn the fuel is introduced into the cylinder, and accordingly perfect combustion takes place. The speed of the engine is controlled by means of the governor acting on the by-pass valves (one for each fuel pump). The by-pass oil valves are opened by arms pivoted on a shaft raised or lowered by the governor, and operate as follows: If only a small amount of fuel is required in the cylinder to overcome the load, the governor holds the by-pass valve open for a lengthened period and a greater amount of the oil is allowed to return to the suction pipe, while, if the load is greater, and consequently more fuel is required in the cylinder to overcome it, the by-pass valves open for a relatively shorter period and then less oil returns to the suction pipe, a greater amount of fuel passing to the cylinder. By this method of governing a very close regulation of speed is effected.

Indicator card from this engine is shown at Fig. 100.

The Diesel engine has created great interest in engineering circles the world over, and many tests have been made of it. Professor Denton, of the Stevens Institute, Hoboken, N. J., in 1898 conducted

a series of tests on this engine, and according to his report of those tests the consumption of fuel was 0.534 lbs. per B. H. P. per hour at full load, and at less than half load 0.72 lbs. per B. H. P. per hour. This is

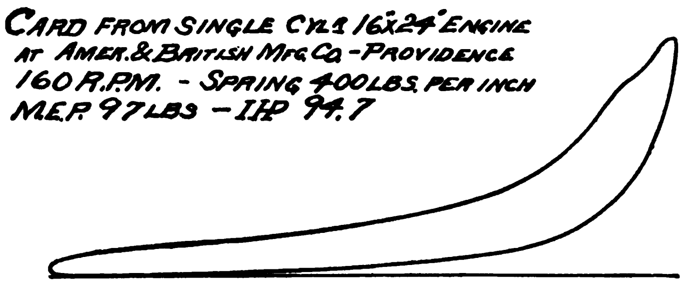


FIG. 100.

equivalent to a thermal efficiency (on the I. H. P.) of 37.7 per cent.

The following is the heat-balance table as shown by Professor Denton:

	PER CENT.
Heat of combustion accounted for by indicated power	37.2
Removed by jacket	35.4
Remainder	27.4
Total heat of combustion	100.0

Another type of the Diesel engine, that made by the manufacturers in Sweden, is shown at Fig. 101.

The following tests were made by Prof. Meyer in 1900 on a German type 30 H. P. engine. The

cylinder 11.8″ diam., 18.1″ stroke, air-pump cylinder 1.9″ diam., 3.1″ stroke. Air was taken from motor cylinder at a pressure of 20 atmospheres and com-

FIG. 101.

pressed to 45 or 60 atmospheres. Negative work in the motor cylinder was equivalent to 5.66 H. P. at 181.

R. P. M. The air pump was not indicated, consequently the effective power is not given. The mean indicated pressure at normal load was approximately 90 lbs. per square inch. The exhaust gases were invisible. Two kinds of fuel were used, American petroleum, specific gravity 0.79, having 18,540 B. T. U. per lb., and Tegern See (Bavaria) crude oil, specific gravity 0.789.*

TABLE VIII.—RESULTS OF TRIALS OF A DIESEL OIL ENGINE (MEYER), 1900.

	American Petroleum.				Raw Tegern See Oil.		
Load on Brake.	Full Load.	Normal.	¾ Load.	Half Load.	Normal.	¾ Load.	Half Load.
Revs. per minute....	177.4	181.1	184.0	183.3	181.2	181.8	185.0
Brake (or actual) H. P., metric......	39.45	30.17	23.81	15.26	30.18	23.5	15.4
Indicated H. P. (motor cyl.)...........	48.2	39.52	33.10	25.02	40.96	33.0	26.4
Mech. efficiency.....	82	76	72	61	73	71	58
Oil used per B. H. P., per hour.......lbs.	0.48	0.45	0.48	0.57	0.47	0.49	0.57
Percentage of heat of oil as useful work............	28	30	28	24	29.8	.....	......

CRUDE OIL VAPORIZER.

On the Pacific Coast crude oil is now being largely used for fuel. In many instances this fuel is used, being vaporized or gasified in a separate apparatus and is then consumed in the ordinary gas engine. This

*"Gas and Petroleum Engines." By Prof. Wm. Robinson. Second edition. Page 777.

apparatus is separate from the engine, the oil being entirely gasified before it reaches the engine cylinder. Such vaporizing apparatus or retorts are made by various manufacturers, but in general principle they are similar. The heat of the exhaust gases from the engine is utilized to heat the retort into which the oil is introduced, where it is gasified.

Mr. Frank H. Bates has drawn attention to these various retorts, which usually consist of a cast-iron chamber enclosing an inner chamber, also of cast iron.* The fuel to be gasified enters the inner ribbed chamber through suitable openings, and the gas is drawn from the chamber through a separate connection from the inner chamber to the engine cylinder. The exhaust gases from the engine are connected to the outer chamber and pass around, heating the inner chamber to a temperature necessary for vaporization. Provision is made to draw off the residue of the crude oil, which is not capable of vaporization, and provision is also made to cleanse the vaporizing chamber of deposit of carbon and other solid matter.

In the "Economist" retort the inner ribbed chamber, or drum, is made to slowly revolve, and, the ribs being spirally shaped, the oil is propelled from end to end and the heat is then equally distributed around the inner chamber. In service where the load is fairly constant, and where opportunity to cleanse the retort occasionally, is afforded, these retorts have given excellent results. For installations, however, such as

*See *Journal of Electricity, Power and Gas,* Vol. XIII., p. 5.

electric railway service, or where the load varies between wide limits and where continuous running is imperative, it is stated that difficulty has been experi-

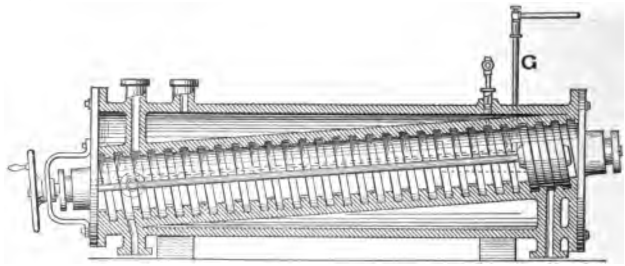


FIG. 102.

enced, due to the fluctuating temperature of the retort heated by the exhaust gases, which involves improperly regulated supply of vapor to the cylinder. To overcome this difficulty with varying loads, Messrs. C. C. Moore & Co. have developed an improved system of using crude oil in connection with gas engines.

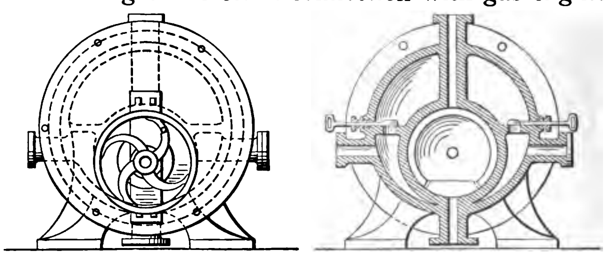


FIG. 103.

The generator, as made by this company, is shown in Figs. 102 to 104, in which are shown a longitudinal elevation of the generator, end elevation, and also the

generator connected up to its drainage chamber for the automatic removal of the deposit. It will be noted from Fig. 102 that a scraper is arranged which can be moved from end to end of the vaporizer by means of the hand wheel. This scraper is shown in Fig. 105. The oil supply is regulated by means of a thermostatic valve, and is automatically maintained at a constant level by this means. The method of operation is as follows:

Oil is first fed into the vaporizing chamber by means of a valve until the level in both this chamber and in the oil feed device is a little above the level of the upper drain pipe. A heating device is then inserted into the exhaust gas passage, heating the vaporizing chamber to about 300° Fahr. The engine is started by means of compressed air, and when in operation air heavily charged with oil vapor passes through the nozzle *G*, Fig. 102, to the engine cylinder. The exhaust gases from the engine afterwards furnish the heat necessary to maintain the vaporizer at a proper temperature; these gases pass around the generator, and thence by the exhaust pipe to the roof. The temperature of this chamber is regulated by the thermostatic valve, which, when the temperature of the vaporizer rises too high, allows the exhaust gases to be bypassed from the vaporizer and pass directly to the roof. The thermostatic device consists of an aluminum tube inserted directly into the vapor chamber, around which the exhaust gases pass. The aluminum tube is closed at its upper end and is attached to a system of levers so arranged as to exaggerate its move-

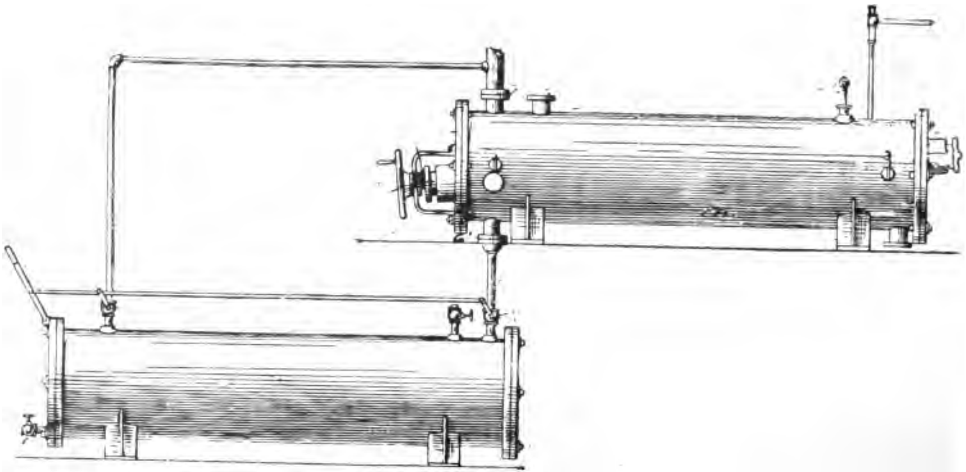


FIG. 104.

ment, caused by the variation in temperature. Accordingly, when the temperature of the vaporizer chamber rises above that required, the expansion of the aluminum tube is arranged to close a needle valve, which allows the pressure of the exhaust gases from the engine to lift a larger valve, thus opening a passage outside the vaporizer, through which the exhaust passes instead of entering the chamber around the vaporizing retort. By this means the temperature of the retort is regulated within very close limits.

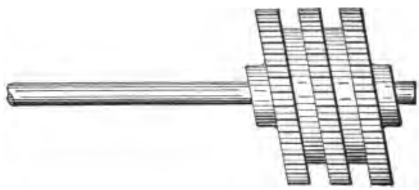
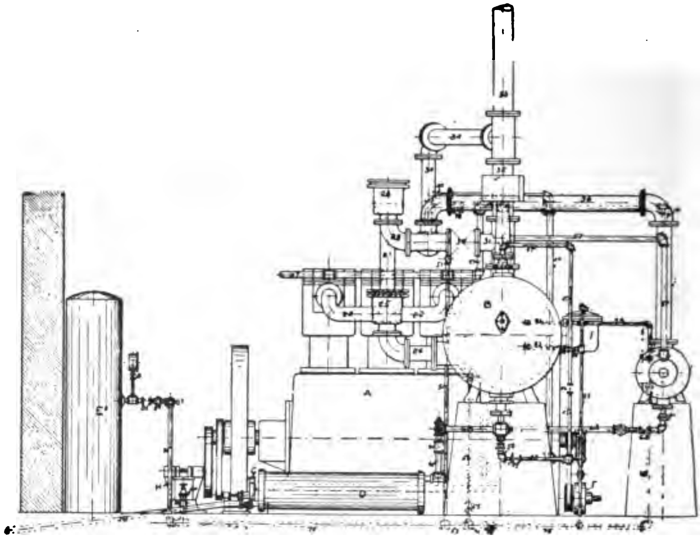
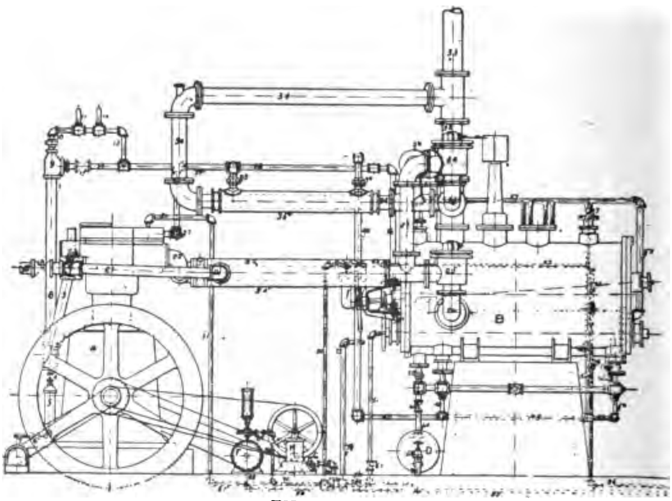


FIG. 105.

The proper level of the liquid fuel to be vaporized is regulated by an automatic ball check valve placed in the chamber marked *I*, Fig. 106, through which the oil passes to the vaporizer. A relief valve is inserted in the supply pump, so that when the valve to the vaporizing chamber is closed the fuel can by this means flow back to the tank. The retort is readily cleansed by means of the scraper already referred to, shown in Fig. 105, which is operated by hand periodically. In the larger size installations made by Messrs. C. C. Moore & Co. more extensive equipment is provided, in which arrangement is made to utilize the heat rejected by the exhaust gases and also



SIDE VIEW.



END VIEW.

FIG. 106.

the heat given off from the water jacket, and in which installations the residue of the oil is partly used also. In these outfits a combination of oil vapor and water gas is formed, two superheaters being added, one of which is heated by the exhaust gases, in which part of the cooling water issuing from the water jacket is turned into steam; the second superheater is heated by the burning of residue oil in connection with compressed air. In this way, it is stated, steam raised to approximately 1600° Fahr. in the chamber *C*, Fig. 106, is mingled with the oil vapor forming the combination of oil vapor and water gas referred to. By the use of this apparatus a greater economy is effected and a greater part of the heat of the fuel utilized.

The following is a brief description of the accompanying illustrations, Figs. 106 and 107:

The three-cylinder Westinghouse gas engine of the vertical type is shown at *A*. The generator by which the crude oil is vaporized is shown at *B*. The superheater (heated by residual oil burners) is marked *C*. The chamber for drainage of residuals is shown at *D*. *H* is an air-compressor operated by belt from the engine crank-shaft. *I* is the automatic oil feed, which maintains the proper level of the oil in the generator. E, E^1 and E^2 are the air storage tanks maintained at a pressure of 160 lbs. per square inch. *F* is the rotary oil pump which raises the fuel from the storage tank underground to the vaporizer. The water-circulating pump which supplies the cooling water to the cylinders is shown at *G*.

A separate vaporizing attachment for using crude

oil of the type already mentioned is shown at Fig. 108. The vaporizer is separate from the engine, being attached to the gas or gasoline engine, where it is required to use crude oil as fuel instead of gas or gasoline. The outfit shown is the Fairbanks-Morse gas or gasoline engine, which has attached to it the outside apparatus for vaporizing the oil, the vaporizer being a

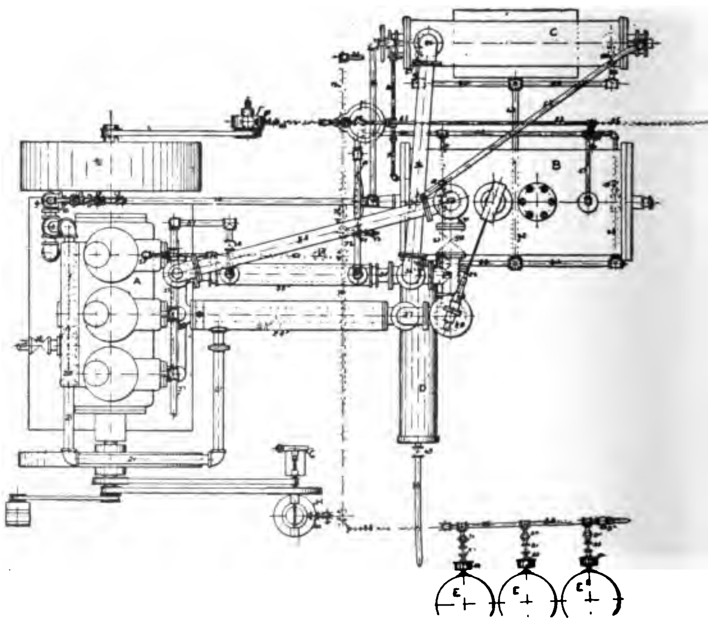


FIG. 107.

The figures shown in Figs. 106 and 107 are not referred to herein, as these illustrations are made from working drawings.

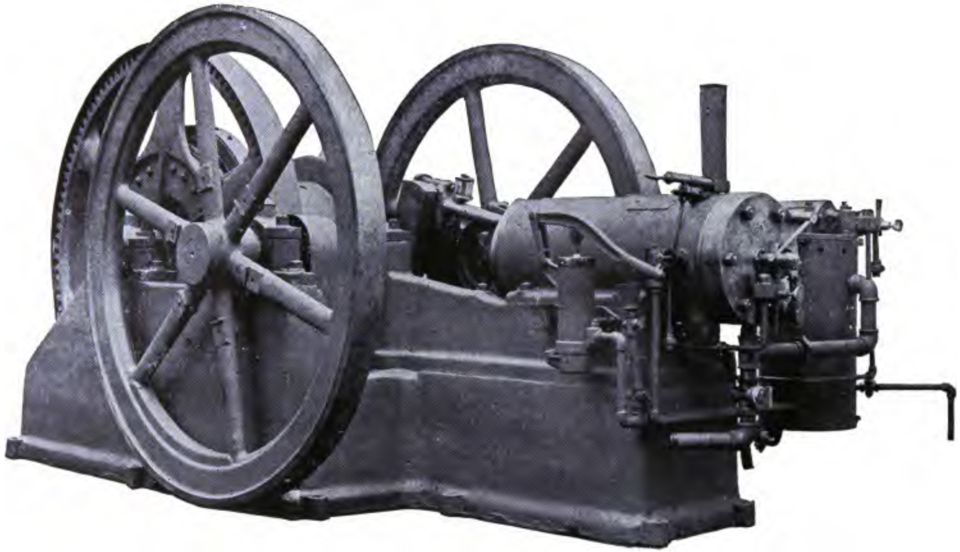


FIG. 108.

(To face p. 228.)

cast-iron chamber into which the liquid oil is injected. This chamber is heated while in operation by the exhaust gases. Before starting it is necessary to use an outside lamp, in order that the chamber may become heated to the temperature required to vaporize the fuel. The oil is mixed with air drawn into the vaporizer and becomes vaporized in this chamber, and is drawn therefrom into the cylinder in the usual way.

As will be seen from the illustration, the engine shown at Fig. 108 is geared directly up to hoisting drum. These outfits are very largely used for mining and similar purposes, where hoisting engines can be readily utilized.

CHAPTER XIII.

FUELS.

THE fuel to be used in the type of engines here discussed is frequently a matter of inquiry, and accordingly a brief description of the various fuels used is given.

The Texas oil, which hitherto has not been so fully treated of elsewhere is discussed more fully than the other fuels.

The supply of petroleum is produced chiefly in the United States of America and in Russia, while it is also found in many other countries in small quantities.

Petroleum is found in the United States in the Central Eastern States, notably Pennsylvania, New York, Ohio and West Virginia; in Texas in the region around Beaumont and Corsicana, in California chiefly in the Kern County, Coalinga, Los Angeles, producing fields. In Russia oil fields are found around Baku and in the range of the Caucasus Mountains.

Paraffin or shale oil, a fuel produced by a slow process of distillation of "shale" and bituminous coal, is also produced in Scotland.

Crude petroleum as it issues or is pumped from the earth contains a variety of hydrocarbons of different characteristics, and after its sediment has settled it is

subjected to a process of refining known as fractional distillation, by which process the various hydrocarbons are separated and are afterwards condensed into the different products known in commerce as benzine, gasoline, naphtha, being the lighter products, having a flash-point below 73° Fahr. Next the illuminating oils, such as W. W. 150° kerosene, White Rose and other brands of a similar composition, are obtained, having a flash-point above 73° Fahr. The next product is gas oil, or fuel oil, used largely for gas-making and also as fuel in internal combustion engines, having a flash-point of about 190°. Lubricating oils, paraffin, wax, vaseline, etc., are afterwards procured, the residue being only a heavy liquid sometimes used for fuel.

The fuels used chiefly in the engines here discussed, as already stated, are the crude oils, the illuminating oils and the fuel or gas oil.

Crude Oils.

In the accompanying tables will be found the characteristics of the crude oils produced from the different Russian oil fields, the American oil fields of the Allegheny region, as well as the oils produced in Texas, California and elsewhere.

The Russian crude oil is heavier than the American product found in the Allegheny region, the average specific gravity of the former being .85, that of the latter being .79.

Texas crude oil, many samples of which have been used by the writer in the Hornsby-Akroyd oil engine,

is a dark, heavy liquid having a specific gravity varying from .861 to .915, the flash-point (open method) being 180° to 195°.

An analysis of this oil by Messrs. Clifford Richardson and E. C. Wallace,* taken from the Lucas well, Beaumont, Texas, 1901, in which the following, it may be mentioned, were the methods of examination, has been made.

The specific gravity was determined in a picnometer at 25° C., the flash-point was taken in a New York State oil tester, the refractive index with an Abbe refractometer at 25° C. The viscosity represents the number of seconds required for the oils to flow from a 100 c.c. pipette, according to the P. R. R. specifications. Volatility was obtained by allowing 20 grm. of crude petroleum to be heated in an open dish $2\frac{1}{2}$ inches diameter, $1\frac{1}{4}$ inches deep, to various temperatures for various periods of time, or until the loss became small enough to neglect. The volatilization then goes on below the boiling point. The vapor not being confined, there is no "cracking." The distillation in Engler's Flask was carried out in the usual way, the distillate between 150° and 300° C. representing the burning oil available commercially.

For the purpose of fractional distillation, about half a litre of oil was distilled in a litre flask of the Engler shape (but larger) supported on a six-mesh iron cloth surrounded by loose bricks covered with asbestos board. The distillate was condensed in an air-con-

*See "Journal of the Society of Chemical Industry," Vol. 20, No. 7.

denser 3 feet long connected with a Bruhl's receiver, where a vacuum of 20 mm. could be maintained. All joints were mercury sealed or of solid glass; access of air or decomposition was prevented. A current of carbon dioxide was conducted to the bottom of the distilling flask to agitate the oil and remove air from the apparatus. The oil was heated by a ring-flame Fletcher burner, and distilled at ordinary pressure as long as there were no signs of cracking. As soon as any decomposition was recognized, or the temperature had reached a high figure, the oil was cooled and the vacuum made. The difference in boiling point at atmospheric pressure and at 20 mm. for hydrocarbons, boiling under 760 mm. at about 320° C., is 117°, a distillate coming over at 317° at atmospheric pressure beginning to distil at 200° in a vacuum of 20 mm. The distillates were then treated twice with an excess of sulphuric acid, washed with dilute soda, dried over sodium, and then determinations repeated. Finally, one of the distillates was treated with a mixture of equal volumes of sulphuric and nitric acid, washed, boiled with sodium and examined.

EXAMINATION OF RESIDUES.—The residues left after evaporation in the open dish, or from either of the methods of distillation, are characteristic and of value in determining the nature of any petroleum, and as to whether it has a so-called asphaltic or paraffin base.

ULTIMATE ANALYSES.—These were made with the precautions which have been found necessary in burning the polymethylene hydrocarbons, which very readily escape complete combustion.

Beaumont oil contains a much larger proportion of unsaturated hydrocarbons removable by sulphuric acid than either Pennsylvania or Ohio petroleum. The Beaumont oil has a high sulphur content and carries, as it comes from the wells, a large amount of hydrogen sulphide in solution. This gas has previously been observed in solution in petroleum, but not in so large quantity as at Beaumont. The sulphuretted hydrogen is largely lost on standing, and more completely on blowing air through it. After such treatment the oil contained 1.75 per cent. of sulphur in the form of sulphur derivatives of the hydrocarbons.

A comparison of the ultimate compositions of the Texas oil with other oils used for fuel shows that, while not equal to Pennsylvania and Ohio oils, owing to the low carbon and high sulphur, it is not inferior to the California petroleums in any marked degree.

TABLE IX.—ULTIMATE COMPOSITION.

	Beaumont.	Penna.*	Ohio.†
Carbon	85.03	86.10	85.00
Hydrogen	12.30	13.90	13.80
Sulphur	1.75	0.06	0.60
Oxygen and Hydrogen	0.92	.....	0.60
Loss on treatment with excess of H_2SO_4. (Sulphuric acid)	39.0	21.0	30.0

*Engler. †Mabery, Noble Co.

TABLE X.—BEAUMONT OIL.

Specific gravity 25° C.	0.912	0.914	0.8014	0.8293
Flash	Ord. Temp.	110°	Ord.	Ord.
Viscosity, P.R.R. pipette	......	75″	42″	37″

TABLE XI.—VOLATILITY IN OPEN DISH.

	Per Cent.	Per Cent.	Per Cent.	Per Cent.
110° C., 230° F.: 7 hours....	19.19	20.0	41.2	47.3
162° C., 325° F. 7 "	31.31	27.0	43.0	58.0
205° C., 400° F. 7 "	57.57	49.0	59.0	68.0
To constant weight—				
105° C., 221° F.: 42 hours	48.0	48.0	48.7	58.7
162° C., 325° F.: 70 "	64.0*	57.0	61.0	71.8†
205° C., 400° F.: 49 "	74.0	74.0	75.0	84.0

* 49 hours. † 42 hours.

TABLE XII.—DISTILLATION: ENGLER'S FLASKS.

	Beaumont.	Ohio.	Pennsylvania.
Distillation begins.............	110° C.	85° C.	80° C.
Below 150° C..........per cent.	2.5	23.0	21.0
150°—300° C. .... "	40.0	21.0	41.0
300°—350° C. .... "	20.0	21.0	14.0
350°—400° C. .... "	25.0	27.0	{ 23.0 { 99.0
Loss on acid treatment (150°—300° C. fraction)...........	10.0	5.0	1.8
150°—260° C..........per cent.	30.0	....	....
Loss on acid treatment. "	8.0	....	....
Percentage of acid used "	7.0	2.5	2.0

TABLE XIII.—SPECIFIC GRAVITY AND REFRACTIVE INDEX.

	Beaumont.		Ohio.		Pennsylvania.	
	Sp. Gr.	Refrac. Index.	Sp. Gr.	Refrac. Index.	Sp. Gr.	Refrac. Index.
Below 150°..	(Amount too small.)		0.7297	1.412	0.7188	1.415
150°—300°..	0.8749	1.473	0.8014	1.442	0.7984	1.437
300°—350°..	0.9089	1.501	0.8404	1.468	0.8338	1.462
350°—400°..	0.9182	1.508	0.8643	1.481	Paraffin	1.470
	After acid treatment.					
150°—300°..	0.8704	1.473	0.8006	1.443	0.7791	1.438

Table XIV.—Calorific Power of Various Descriptions of Petroleum, Etc. (B. Redwood.)

Description of Oil.	Specific Gravity at 0° C.	Chemical Composition.			Coefficient of Expansion.	Am't of Water Evaporated Per Unit of Fuel.	Effect in Heat Units.
		Carbon.	Hydrogen.	Oxygen.			
Heavy Petroleum from West Virginia.......	0.873	83.5	13.3	3.2	0.00072	14.58	10,180
Light Petroleum from West Virginia.......	0.8412	84.3	14.1	1.6	0.000839	14.55	10,223
Light Petroleum from Pennsylvania........	0.816	82.0	14.8	3.2	0.00084	14.05	9,963
Heavy Petroleum from Pennsylvania........	0.886	84.9	13.7	1.04	0.000721	15.30	10,672
American Petroleum..	0.820	83.4	14.7	1.9	0.000868	14.14	9,771
Petroleum from Parma	0.786	84.0	13.4	1.8	0.000706	13.96	10,121
Petroleum from Pechelbronn	0.912	86.9	11.8	1.3	0.000767	14.30	9,708
Petroleum from Pechelbronn	0.892	85.7	12.0	2.3	0.000793	14.48	10,020
Petroleum from Schwabweiler	0.861	86.2	13.3	0.5	0.000858	15.36	10,458
Petroleum from Schwabweiler	0.829	79.5	13.6	6.9	0.000843	.....	......
Petroleum from Hanover	0.892	80.4	12.7	6.9	0.000772	.....	......
Petroleum from Hanover	0.955	86.2	11.4	2.4	0.000641	.....	......
Petroleum from East Galicia.............	0.870	82.2	12.1	5.7	0.000813	14.23	10,085
Petroleum from West Galicia.............	0.885	85.3	12.6	2.1 (N. O.)	0.000775	14.79	10,231
Shale Oil from Ardèche	0.911	80.3	11.5	8.2 (O. S. N.)	0.000896	12.24	9,046
Coal Tar from Paris Gasworks	1.044	82.0	7.6	10.4	0.000743	12.77	8,916
Petroleum from Balakhany................	0.822	87.4	12.5	0.1	0.000817	.....	11,700
Light Petroleum from Baku...............	0.844	86.3	13.6	0.1	0.000724	16.40	11,460
Heavy Petroleum from Baku...............	0.938	86.6	12.3	1.1	0.000681	15.55	10,800
Petroleum residues from Baku Factories	0.928	87.1	11.7	1.2	0.00091	.....	10,700
Petroleum from Java..	0.923	87.1	12.0	0.9	0.000769	15.02	10,831
Heavy Oil from Ogaio	0.985	87.1	10.4	2.5	0.0008685	14.75	10,081

TABLE XV.—COMPOSITION, PHYSICAL PROPERTIES, ETC., OF VARIOUS DESCRIPTIONS OF PETROLEUM.
(B. REDWOOD.)

Description of Petroleum, etc	Elementary Composition			Percentage of Distillate at °C.										Specific Gravity at °C.				Coefficient of Expansion.	Composition of Distillate.			Specific Gravity of Distillate at °C.		Specific Gravity of Residue at °C.		Calorific Power.
	C	H	O	100°	120°	140°	160°	180°	200°	220°	240°	260°	280°						C	H	O					
Heavy Virginia Petroleum (135 m.)	83.5	13.3	3.2	1.0	....	1.3	....	12.0	....	....	....	....	....	0°	0.873	50.1°	0.853	0.00072	85.3	13.9	0.8	13°	0.819	13.3°	0.864	10,180
Light Virginia Petroleum (200 m.)	84.3	14.1	1.6	1.3	4.3	11.0	17.7	25.2	28.5	....	....	...	....	0°	0.8412	50.1°	0.808	0.000839	84.0	14.4	1.6	14°	0.762	14°	0.860	10,2[illegible]3
Light Pennsylvania Petroleum (200 m.)	82.0	14.8	3.2	4.3	10.7	16.0	23.7	28.7	31.0	....	....	....	....	0°	0.816	50.1°	0.784	0.00084	85.1	14.3	0.6	13.6°	0.735	13.6°	0.845	9,963
Heavy Ohio Petroleum	84.2	13.1	2.7	...	....	....	....	....	....	....	....	....	....	0°	0.887	53°	0.853	0.000748	85.4	14.0	0.6	.....	.....	14.8°	0.860	10,399
Heavy Pennsylvania Petroleum (200 m.)	84.9	13.7	1.4	...	....	....	....	....	...	....	....	....	12.0	0°	0.886	50.1°	0.853	0.000721	At 350° 86.7 85.4	12.2 13.8	1.1 0.8	14° 13.2°	0.762 0.802	13°	0.875	10,672
Java Petroleum	87.1	12.0	0.9	1.0	1.0	....	....	7.7	15.0	22.3	24.3	..	....	0°	0.923	53°	0.888	0.000764	86.2	12.2	1.6	.....	0.811	13.3°	0.935	10,831
" "	83.6	14.0	2.14	0.8	3.0	9.3	16.3	22.0	27.8	....	....	....	....	0°	0.827	53°	0.78[illegible]	0.000923	83.9	14.1	2.0	13.1°	0.778	13.3°	0.914	9,593
" "	85.0	11.2	2.8	...	....	....	....	....	....	2.3	4.0	9.0	....	0°	0.972	53°	0.945	0.000652	85.1	12.2	1.7	13.2°	0.762	13.2°	0.942	10,183
East Galicia Petroleum	82.2	12.1	5.7	2.1	4.6	8.7	13.7	14.3	21.7	25.3	32.3	....	....	0°	0.870	50°	0.836	0.000813	80.5	13.6	5.9	21°	0.778	21°	0.901	10,005
West Galicia Petroleum	85.3	12.6	2.1	...	4.0	9.8	14.3	23.3	27.0	30.7	36.7	....	....	0°	0.885	.....	0.852	0.000775	83.8	12.9	3.3	21°	0.786	21°	0.931	10,231

TABLE XVI.—OIL FUEL. (B. REDWOOD.)

Locality.	Fuel.	Sp. Gr. at 0° C.	Chemical Composition. Carbon.	Hydrogen.	Oxygen.	Heating Power. Actual Calorimetric (lb. C. Units.)	Calculated (lb. C. Heat Units.)
Russian.............	Petrol. refuse	0.928	87.1	11.7	1.2	......	11,018
"	Astatki	0.9	84.94	13.96	1.2	10,340	11,626
Caucasian...........	Heavy Crude	0.938	86.6	12.3	1.1	10,800	11,200
" (Novorossisk)	" "	....	84.9	11.63	1.458	10,328	......
Pennsylvanian......	" "	0.886	84.9	13.7	1.4	......	10,672
American...........	" "	.....	86.894	13.107	.....	10,912	......
"	Refined	.....	85.491	14.216	0.293	11,045	......
"	Double "	.....	80.583	15.101	4.316	11,086	......
"	Crude "	.....	83.012	13.889	3.099	11,094	......

TABLE XVII.—CALORIFIC POWER OF CRUDE PETROLEUM. (B. REDWOOD.)

	Sp. Gr.	Calories.
Heavy Lubricating Oil, White Oak, Western Virginia	0.873	10,180
Light Illuminating Oil, Oil Creek, Pa.	0.816	9,963
Oil from Dandang, Leo Rembang, Java.	0.923	10,831
Light Oil from Baku.................	0.884	11,460
Oil from Western Galicia............	0.885	10,231
" " Eastern "	0.870	10,005
" " Parma	0.786	10,121
" " Schwabweiler	0.861	10,458

California Crude Oil.

The crude petroleum procured in the various oil fields of California, from the information available, appears to vary considerably in its characteristics. According to the report of the Chamber of Commerce of San Francisco, in 1902 the oil-producing fields of Kern River, Coalinga, Los Angeles, Fullerton, with many others, in which over 2,000 wells were in operation, produced an average daily supply of over 37,000 barrels. It has been used hitherto chiefly for fuel purposes, and having in most instances an asphaltum base, is most suitable for this purpose. The characteristics of the oil vary so widely, however, that while some samples can only be used for fuel, that produced in other wells would yield illuminating oils on distillation in considerable quantity. The following is the analysis of two samples of the distillates from the Kern River field:

		(Flash test was taken, using the open method.)
Gravity	0.901	0.859
Beaumé	26.2°	34°
Flash	169° F.	119° F.

According to Mr. Paul Prutzman,* the oil produced in Coalinga oil field varies from 11.5° Béaume to 45°. The viscosity of various samples varies from 68 to 296, while the flash point varies from 220° to 278° F. This writer also refers to the refining qualities of various samples, from which it would appear that on distillation

* *Pacific Oil Reporter,* Vol. 4, No. 35.

while some of the oil would give far greater amount of kerosene (42° B.) than others, the average yield of kerosene on distillation would be about 14 per cent; while the engine distillate (48 to 52° B.) given off from the above-mentioned samples would also vary considerably in quantity, the average would, however, be approximately 14 per cent—the products which were obtained being of a lighter quality than kerosene were inconsiderable. This fuel is now used on the Pacific coast in large quantities, both under boilers for generating steam, in gas engines having first been gasified, as explained in Chapter XII., as well as in the oil engine proper, where it is vaporized by the same methods as with kerosene.

Fuel Oil.

The oil known as fuel or gas oil, as already stated, is procured in the process of fractional distillation after the lighter oils and the illuminating oils have been taken off. Various samples of this fuel have come within the writer's notice, the characteristics of which have varied considerably, as will be seen from the following table:

FUEL OIL.

Specific gravity ..	0.832	.878
Beaumé	36°	30.2°
Flash-point	144° F.	298° F.
Fire test	183° F.	247° F.

This fuel is much used in oil engines in the United States. With the heavier grades a slight deposit of carbon is left in the engines, which requires periodical removing.

CHAPTER XIV.

MISCELLANEOUS.

OWING to the increasing use of the metric system, the following comparisons of United States and metric measures and weights, etc., prepared by C. H. Herter, are added. The unit of length is the metre = 39.37 inches; the unit of capacity is the litre = 61.0236 cubic inches; the unit of weight is the gramme = 15.43236 grains.

The following prefixes are used for subdivisions and multiples: Milli = $\frac{1}{1000}$, Centi = $\frac{1}{100}$, Deci = $\frac{1}{10}$; Deca = 10, Hecto = 100, Kilo = 1000, and Myria = 10,000. In abbreviations the subdivisions begin with a small letter, the multiples with a capital letter. For example:

Millimetre	(.001)	denoted by	mm.
Centimetre	(.01)	"	cm.
Decimetre	(.1)	"	dm.
Metre	(1.)	"	m.
Decametre	(10.)	"	Dm.
Hectometre	(100.)	"	Hm.
Kilometre	(1000.)	"	Km.
1 Centiare	(1 m^2)	"	ca.
Square decimetre		"	dm^2.
Cube metre		"	m^3.
Decilitre		"	dl.
Milligram		"	mg.
Kilogram		"	Kg.

U. S. to METRIC

CUBIC AND CAPACITY MEASURES

1 cubic inch = 0.016387 l. .... = 16.3871 cm^3.
1 cubic foot ..... = 0.028317 m^3. = 28.317 l.
1 cubic yard .... = 0.76456 m^3.
1 U. S. gallon .... = 3.7854 l.
1 quart (liq.) .... = ($\frac{1}{4}$ gallon) = 0.94636 l.
1 barrel (31.5 gals.) .... = 1.1924 Hl.

WEIGHTS

1 grain (= $\frac{1}{7000}$ lb.) ...... = 0.0648 g. (gramme)
1 ounce (avdup.) .... = 28.35 g.
1 pound (avdup.) .. = 453.592 g. = 0.4536 Kg.
1 ton of 2240 lbs. .. = 1.016 T. = 1016.05 Kg.
1 ton of 2000 lbs. .. = 0.9072 T. = 907.185 Kg.

COMPOUND UNITS

1 grain per cu. foot = 2.28834 grammes per m^3.
1 lb. per cu. foot = 16.01837 Kg. per m^3.

METRIC to U. S.

CUBIC AND CAPACITY MEASURES

1 m^3. = 1 stere = 35.3145 cu. ft. = 1.308 cu. yds.
1 cm^3 .... = 0.06102 cu. inch
1 dm^3. = 1 litre = 61.02338 cu. inches
or .03531 cu. feet
or 1.0567 liq. quarts
or 0.2642 U. S. gallons
1 Hl. = 3.53145 cu. feet
or 0.838636 barrel (31.5 U. S. gal. per bbl.)

WEIGHTS

1 g. (gramme) = 15.432 grains
or 0.035274 avdup. ounces
1 Kg. .... = 2.20462 avdup. lbs.
1 T. (tonne) = 0.9842 ton of 2240 lbs.
or 19.684 cwts., or 1.1023 ton of 2000 lbs.
or 2204.62 lbs.

COMPOUND UNITS

1 gramme per m^3. = 0.436998 grains per cu. ft.
1 Kg. per m^3. = 0.062428 lbs. per cu. ft.

U. S. to METRIC

PRESSURES

1 lb. per sq. in. .... = 0.070307 Kg. per cm^2.
1 lb. per sq. ft. .... = 4.8824 Kg. per m^2.
1 atmosphere (14.7 lbs. per sq. inch)
= 1.03326 Kg. per cm^2.

HEAT UNITS

1 B. T. U. = quantity of heat required to raise temperature of a lb. water, 1° F.
1 B. T. U. = 0.252 cal.
1 B. T. U. per sq. ft. ...... = 2.7124 cal. per m^2.
1 B. T. U. per cu. ft. ...... = 8.8991 cal. per m^3.

UNITS OF WORK

1 foot-pound .... = 0.138255 m. Kg.
33,000 ft.-lbs. per min. (1 engl. H. P.)
= 4562.429 m. Kg.
1 engl. H. P. .... = 1.01387 met. H. P.

QUANTITIES PER HORSEPOWER

1 sq. ft. p. engl. H. P. = 0.091632 m^2. p. met. H. P.
1 cu. ft. " " = 0.02793 m^3. " "
1 U. S. gal. " " = 3.73364 litres " "
1 lb. per " " = 0.447386 Kg. " "

UNIT OF VELOCITY

1 foot per min. .... = 0.016⅔ ft. per sec.
= 0.00508 m. per sec.

METRIC to U. S.

PRESSURES

1 gramme per mm^2. = 1.42234 lbs. per sq. inch
1 Kg. per cm^2. ...... = 14.2234 lbs. per sq. inch

HEAT UNITS

1 calorie = quantity of heat required to raise temperature of 1 Kg. water, 1° C.
(1 lb. calorie = quantity of heat required to raise temperature of 1 lb. water, 1° C., or = 1.8 B. T. U. This unit should never be used.)
1 cal. .... = 3.9683 B. T. U.
1 cal. per m^2. .... = 0.36867 B. T. U. per sq. ft.
1 cal. per m^3. .... = 0.112371 B. T. U. per cu. ft.

UNITS OF WORK

1 m. Kg. .... = 7.233 foot-lbs.
1 metric H. P. = 75 m. Kg. per sec. = 542.475 ft.-lbs. per sec., or 32548.49 ft.-lbs. per min. = 0.98632 engl. H. P.

QUANTITIES PER HORSEPOWER

1 m^2. per met. H. P. = 10.9132 sq. ft. per engl. H. P.
1 m^3. " " = 35.8043 cu. ft. " "
1 dm^3. or litre " = 0.035804 cu. ft., or
= 0.267835 U. S. gals. per engl. H. P.
1 Kg. per met. H. P. = 2.2352 lbs. per engl. H. P.

UNIT OF VELOCITY

1 m. per sec. .... = 3.28083 ft. per sec., or
= 196.85 ft. per min.

U. S. to METRIC	METRIC to U.S.
LINEAR	**LINEAR**
1 inch......... = 25.4 mm.	1 m. = 39.37 in. or 3.2808 ft. or 1.0936 yds.
1 foot......... = 0.3048 m.	1 mm.......... = 0.03937 inch
1 yard......... = 0.9144 m.	1 cm.......... = 0.3937 inch
1 mile......... = 1.6093 Km.	1Km. = 1093.61yds. or 0.621 mile
SQUARE	**SQUARE**
1 sq. inch...... = 6.4516 cm².	1 m². = 10.7639 sq. ft. or 1.196 sq. yards
1 sq. foot = 929.03 cm² or 0.0929 m².	1 mm²..... = 0.00155 sq. inch
1 sq. yard...... = 0.8361 m².	1 cm²...... = 0.155 sq. inch

Fire Insurance.

The following are the requirements of the New York Board of Fire Underwriters for the Installation and use of Kerosene Oil Engines:

Location of Engine:—Engine shall not be located where the normal temperature is above 95° Fahr., or within ten feet of any fire.

If enclosed in room, same must be well ventilated, and if room has a wood floor, the entire floor must be covered with metal and kept free from the drippings of oil.

If engine is not enclosed, and if set on a wood floor, then the floor under and three feet outside of it must be covered with metal.

Oil Feed Tank.—If located inside of building, shall not exceed five gallons capacity, and must be made of galvanized iron or copper, not less than No. 22 B. & S. gauge, and must be double seamed and soldered, and must be set in a drip pan on the floor at the base of the engine.

Tanks of more than five gallons capacity must be made of heavy iron or steel, be riveted, and be located, preferably, underground outside of the building. If there is no space available outside the building for a tank, it may, by written permission from this Board, be located in an approved vault attached to the building, or in a non-combustible and well-ventilated compartment inside the building; but no such tank shall exceed five barrels capacity.

Tanks, irrespective of the method of feed, must not be located above the floor on which the engine is set.

The base of an engine must not be used in lieu of a tank as a receptacle for feed oil. A tank, if satisfactorily insulated from the heat of the engine and approved by the Board, may be placed inside of the base.

In starting an engine, gas only, properly arranged, must be used to heat the combustion chamber.

A high-grade kerosene oil must be used, the flash test of which shall be not lower than 100° Fahr.

Oily waste and rags must be kept in an approved self-closing metal can, with legs to raise it six inches above the floor.

The supply of oil, unless in an approved tank outside the building, or in a non-combustible compartment, as above provided for, shall not exceed one barrel, which may be stored on the premises, provided same is kept in an unexposed location ten feet distant from any fire, artificial light and inflammable material, and oil drawn by daylight only.

A drip pan must be placed under the barrel.

Empty kerosene barrels must not be kept on the premises.

TABLE XVIII.—TESTS OF VARIOUS OIL ENGINES MADE IN EDINBURGH.

ENGINES.	Crossley Bros., Ltd.	Campbell Gas Engine Co.	Campbell Gas Engine Co.	R. Stephenson & Co.	Blackstone & Co.	Blackstone & Co.	Blackstone & Co.	Tangyes, Ltd.	Pollock, Whyte and Waddell.	R. Cundall & Son.
Diameter of cylinder, inches	10	12½	9½	7	6	7	9½	11	10	8¾
Stroke, inches....	18	21	18	12	12	14	18	16	18	15
Price of oil per gal. delivered Edin., pence..	6½	6½	6½	6½	6½	6½	6½	6½	6½	6½
FULL POWER TRIAL:										
Brake horsepower....	15.5	18.93	13.87	3.14	5.21	8.13	12.6	18.06	10.64	8.77
Total oil used per hour, lb.	12.29	22.74	14.74	5.13	4.34	6.78	9.40	14.56	12.31	8.43
Oil per BHP per hour, lb.	.793	1.20	1.06	1.63	.833	.836	.746	.806	1.15	.962
Cost per hour (total), pence	10.08	17.88	11.60	4.20	3.42	5.35	7.42	11.50	10.05	6.86
" per BHP per hour, pence	.65	.94	.83	1.33	.656	.658	.588	.636	.938	.782
HALF POWER TRIAL:										
Brake horsepower....	7.71	10.59	6.73	1.31	2.84	4.84	6.59	9.95	4.69	4.35
Total oil used per hour, lb.	8.00	15.52	7.985	3.78	3.125	4.975	6.75	9.35	10.75	6.496
Oil per BHP per hour, lb.	1.037	1.466	1.186	2.88	1.099	1.03	1.024	.939	2.23	1.57
Cost per hour (total), pence	6.56	12.22	6.28	3.08	2.46	3.92	5.32	7.38	8.77	5.27
" per BHP per hour, pence	.85	1.152	.933	2.35	.865	.812	.807	.741	1.82	1.275
LIGHT POWER TRIAL:										
Total oil used per hour, lb.	4.03	8.23	3.8	4.43	1.69	2.75	3.4	3.375	5.375	4.24
Cost per hour, pence.......	3.30	6.47	2.99	3.62	1.33	2.17	2.68	2.67	4.38	3.44
MAXIMUM POWER TRIAL:										
Brake horsepower.........	18.01	25.55	14.89	3.14	6.68	10.66	19.7	20.66	19.85	10.54

TABLE XIX.—TESTS OF VARIOUS OIL ENGINES MADE IN EDINBURGH.

ENGINES.	Crossley Bros., Ltd.	Campbell Gas Engine Co.	Campbell Gas Engine Co.	R. Stephenson & Co.	Blackstone & Co.	Blackstone & Co.	Blackstone & Co.	Tangyes, Ltd.	Pollock, Whyte and Waddell.	R. Cundall & Sons.
Duration of trial hours.... . .. .—	3.762	4	4	1.266	4	4	4	4	4	2
Time taken to start full load, miuutes..	18¼	31	14	10	11	.10	16	15	13½	11
BRAKE HORSEPOWER:										
Circumference of flywheel, effective, ft.	11.322	17.586	15.952	14.214	10.936	14.040	17.529	16.022	15.845	14.372
Load on brake, lb..	224.5	204	147	41	70	98	168	204.75	112	96.25
Spring balance reading, lb............	3	15	11.37	12	8.55	10.3	43.4	18.82	11.5	7.54
Net load on brake, lb.	221.5	189	135.63	29	61.45	87.7	124.6	185.93	100.5	88.71
Revolutions per minute, mean.........	204	188	210	252	256	218	190.3	200.1	220.5	227.7
Brake horsepower....	15.5	18.93	13.87	3.14	5.21	8.13	12.6	18.06	10.64	8.77
INDICATED HORSEPOWER:										
Diameter of cylinder, inches..	10	12.5	9.5	7	6	7	9.5	11	10	8.75
Stroke, inches.	18	21	18	12	12	14	18	16	18	15
Mean effective pressure, lb. per sq. in.	64.52	49.5	—	39	—	—	56	62.2	—	—
Explosions per minute, mean	87.25	76	—	118.5	—	—	81.4	89.75	—	—
Indicated horsepower.....	20.09	24.48	—	5.39	—	—	14.68	21.43	—	—
Mechanical efficiency.................	.771	.773	—	.582	—	—	.858	.842	—	—
OIL CONSUMPTION:										
Description of oil used in trial.........	Royal Daylight	Russolene	Russolene	Royal Daylight	Russolene	Russolene	Russolene	Russolene	Royal Daylight	Royal Daylight
Specific gravity............	.793	.826	.826	.796	.825	.825	.825	.823	.797	.800
Total oil used, engine and lamps, lb....	46.25	90.97	58.99	6.5	17.375	27.125	37.625	58.25	49.25	16.875
Oil per I.H.P. per hour, lb...........	.611	.928	—	.952	—	—	.640	.679	—	—
" " B.H.P. " " "	.793	1.200	1.200	1.63	.833	.836	.746	.806	1.15	.962

INDEX

A MANUAL ON

THE CARE AND HANDLING

OF

ELECTRIC PLANTS.

Written for the practical engineer and adapted to the United States military Service. Including Dynamos, Motors, Wiring, Storage Batteries, Testing Instruments, Incandescent Lamps, Photometry and a chapter on the Oil Engine.

By NORMAN H. SCHNEIDER.

Late Electrical Expert, Southern Artillery District, New York.

Author of "Induction Coils and Coil Making," " Notes on United States Army Power Plants," etc.

This manual is intended as a practical handbook for electricians, engineers' assistants and all who are interested in the operation of commercial or military electric plants. The basis of the work were a number of notes and memoranda accumulated by the author during ten years of practical work and upon several courses of lectures delivered at Fort Wadsworth to officers of the U. S. Artillery, and also to non-commissioned officers." The chapter on incandescent lamps is especially valuable as this is a subject very little touched upon in other works. The selection of tables will be found very useful for reference. *Contents of Chapters:* 1. The Electric Current, Insulators, Conductors, Series and Multiple Connections, Wiring, etc.; 2. Dynamos and Motors, Varieties of Motors, Management, Equalizers, Starting boxes, Sparking and Heating Brushes, Practical Hints, etc.; 3. Electrical Measuring Instruments and how to use them; 4. The Storage Battery and its management, Testing, Equipments, Fluids, various Switchboards and their working, etc.; 5. The Incandescent Lamp, Testing, Life of Lamps, Photometry, etc.; 6. The Oil Engine, Belting, Lining up Engine, Pulleys, etc.; Index. 113 pages, illustrated with 66 original drawings and numerous useful tables.

Bound in limp leather, pocket size. By mail for $1.00

25c. BOOKS.

ELECTRICITY. The study of, and its laws for beginners, comprising the laws of electric current generation and flow, Ohm's law, galvanism, magnetism, induction, principles of dynamos and motors, wiring, with explanations of simple mathematics as applied to electrical calculations. By N. H. SCHNEIDER. With 55 original illustrations and 6 tables.

DRY BATTERIES. A practical handbook on the designing, filling and finishing of dry batteries, with tables, for automobiles, gas engine, medical and coil work, electric bells, alarms, telephones, experiments and all purposes requiring a first-rate battery. Fully illustrated with 30 original drawings.

ELECTRICAL CIRCUITS AND DIAGRAMS. Being a selection of original up-to-date and practical diagrams for installing annunciators, alarms, bells, electric gas lighting, telephones, electric power light and wiring circuits, induction coils, gas engine igniters, dynamos and motors, armature windings. By N. H. SCHNEIDER.

ELECTRIC BELLS AND ALARMS. How to install them. By N. H. SCHNEIDER. Including batteries, wire and wiring, circuits, pushes, bells, burglar alarms, high and low water alarms, fire alarms, thermostats, annnuciators, and the locating and remedying of faults. With 56 original diagrams.

MODERN PRIMARY BATTERIES. Their construction, use and maintenance, including batteries for telephones, telegraphs, motors, electric lights, induction coils, and for all experimental work. By N. H. SCHNEIDER. 94 pages, 55 illustrations. The best and latest American book on the subject.

EXPERIMENTING WITH INDUCTION COILS. H. S. NORRIE, author of "Induction Coils and Coil Making." A most instructive little book, full of practical and interesting experiments, fully explained in plain language with numerous hints and suggestions for evening entertainments. Arranged under the following headings: Introduction; The Handling of Ruhmkorff Coil; Experiments with Sparks; Effects in the Vacuum; Induction and Wireless Telegraphy. With 36 original illustrations. [In the press]

SMALL ACCUMULATORS. How made and used, by P. MARSHALL. Giving full descriptions how to make all the parts, assemble them, charge the cells and run them, with examples of their practical application. Useful receipts and memoranda and a glossary of technical terms. 80 pages, 40 illustrations, paper.

ELECTRIC GAS LIGHTING. How to install Electric gas igniting apparatus including the jump spark and multiple systems for all purposes. Also the care and selection of suitable batteries, wiring and repairs, by H. S. NORRIE. 101 pages, 57 illustrations, paper.

25c. BOOKS.

SIMPLE ELECTRICAL WORKING MODELS. How to make them and how to use them. With 43 illustrations.

TELEPHONES AND MICROPHONES. Making and using simple forms of telephones and microphones, with 29 illustrations.

SMALL ELECTRIC MOTORS. How to make and use them, including design, examples of small motors, and their applications, speed controllers, starters, fuses, etc. 48 illustrations.

ELECTRIC LIGHTING for amateurs. The installation of electric light on a small scale, construction of lamps and lamp holders, switches, batteries and their connections. With 45 illustrations.

INDUCTION COILS. A practical handbook on the construction and use of shock and spark coils. With 35 illustrations.

X-RAYS SIMPLY EXPLAINED. The theory and practical application of Radiography. 10 illustrations and 6 plates.

STATIC ELECTRICITY. Simple experiments in. A series of instructive and entertaining electrical experiments with simple and inexpensive apparatus. With 51 illustrations.

SIMPLE SCIENTIFIC EXPERIMENTS. How to perform entertaining and instructive experiments with simple home-made apparatus. With 59 Illustrations.

SMALL ELECTRICAL MEASURING INSTRUMENTS, describing the making and using of the different instruments fully illustrated.

SMALL DYNAMOS AND MOTORS. How to make and use them. A practical handbook, by F. E. POWELL. Contents of Chapters: 1. General Considerations. 2. Field Magnets. 3. Armatures. 4. Commutators and Other Details. 5. Tables of Windings. 6. How to Build a Small Machine. 7. Useful Data. 8. Testing and Repairing. 76 pages, fully illustrated with detail drawings.

UNIVERSAL TIME CARD MODEL. By setting to the desired hour at any one place the movable model will show at a glance the actual time of all the other places in the world. Printed in two colors.

CROSS SECTION BOOKS 25c. each.

THE HANDY SKETCHING BOOK. Size 5x8, scale 8 to 1 in.
THE HANDY SKETCHING PAD. Size 8x10, scale 8 to 1 in.
ELECTRICIANS' SKETCHING BOOK. Size 5x8, scale 10 to 1 in.
ELECTRICIANS' SKETCHING PAD. Size 8x10, scale 10 to 1 in.
PLOTTING PAD. Size 9x11, scale 16 to 1 in.

Electric Bell Fitting.—A practical handbook on the fitting up and maintenance of electric bells and all the necessary apparatus. By F. C. Allsop. CONTENTS OF CHAPTERS.—(1) Wiring and wires (2) Pushes, pulls, contacts and switches. (3) Bells and relays. (4) Indicators. (5) Burglar and fire alarm contacts. (6) Batteries. (7) Connecting up. (8) The detector and localizing faults. (9) Portable sets. Index. Tenth edition. xv + 170 pages. 186 illustrations and folding plates, 12mo. Cloth $1.25.

Electric Bell Construction.—A practical treatise on construction of electric bells, indicators and similar apparatus. By F. C. Allsop. CONTENTS.—*Electricity and Magnetism.*—Galvanic or Primary Batteries; Leclanché Battery; List of Conducting Substances; List of Insulating Materials; The Magnetic Field; Lines of Magnetic Force; Electro-magnet; Winding Bobbins of Electro-magnets; Table of Resistances; Weights and Sizes of Copper Wire. *Bells.*—Construction of Trembling Bells, with details; Construction of Single Stroke Bells, with details; Construction of Continuous Ringing Bells, with details; Construction of the Jansen Electric Bell, with details; Construction of Electric Gongs, with details; Construction of Single Stroke Bells for long distances, with details; Table giving length and diameter of iron Cores, and the amount and sizes of Wire for different sized Bells. *Indicators.*—Drop Shutter or Moving Disks, requiring to be re-set by hand; Electrical Throw-backs; Full details of Mechanical Indicators; Details for Electrical Indicators. *Relays.*—Unpolarized relays; Polerized relays; Details of relays commonly used on Bell Circuits; Continuous ringing attachments. *The Magneto Generator and Bell.*—Its Construction and Use; and complete details of parts, etc. *Galvanometer.*—The Construction and Use of the Detector, or Lineman's Galvanometer, with detail drawings. With Complete Index. 131 pages, 177 illustrations, 12mo. Cloth, $1.25.

Small Dynamo. Notes on Design of. By G. Halliday. This book has been mainly prepared for the purpose of supplying drawings of a small dynamo of a well-known type to enable students to better understand the construction of this machine. 79 pages, illustrated, cloth, with a number of drawings to scale. $1.00‡.

The Phonograph and how to Construct it. With a chapte on Sound. By W. Gillett. A practical work written in good plain language, with a complete set of scale drawings, 87 pages, 12mo. Cloth, $2.00.

Transformer Design.—A treatise on their design, construction and use. By George Adams. The author has avoided historical matter and the use of mathematical analysis. The main object kept in view throughout the work has been to indicate the most direct way of designing a transformer. vi + 75 pages, 34 illus trations, 12mo. Cloth, $1.50.

Dynamo-Electric Machinery

VOL. I.—CONTINUOUS CURRENT.

BY

SILVANUS P. THOMPSON, D.Sc., B.A., F.R.S.

7th Edition Revised and Greatly Enlarged.

CONTENTS OF CHAPTERS.

25c. BOOKS.

MODEL BOILER MAKING. Contains full instructions for designing and making model stationary, marine and locomotive boilers. Fully illustrated with original working drawings.

METAL WORKING TOOLS AND THEIR USES. A Handbook for Young Engineers and Apprentices. Shows how to use simple tools required in metal working and model making. Illustrated.

SIMPLE MECHANICAL WORKING MODELS. How to make and use them, including stationary engine locomotive, steamboat, waterwheel, etc. With 34 illustrations.

MODEL STEAMER BUILDING. A practical handbook on the design and construction of model steamer hulls, and fittings, with 39 scale drawings.

MACHINERY FOR MODEL STEAMERS. On the design, construction, fitting and erecting of engines and boilers for model steamers, with 44 scale drawings.

THE SLIDE VALVE. Simply explained for working engineers. Fully illustrated.

THE LOCOMOTIVE, simply explained. A first introduction to the study of the locomotive engine, their designs, construction and erection, with a short catechism, and 26 illustrations.

THE BEGINNER'S GUIDE TO THE LATHE. An elementary instruction book on turning in wood and metal. By P. MARSHALL. 76 pages, 75 illustrations.

GAS AND OIL ENGINES. A practical handbook on, with instructions for care and running. Illustrated.

STANDARD SCREW THREADS. A Guide to Standard Screw Threads and Twist Drills. (Small sizes.) Illustrated.

STEAM TURBINES. How to design and build them. A practical handbook for model makers. Contents of Chapters. 1. General Consideration. 2, Pressure Developed by an Impinging Jet; Velocity and Flow of Steam Through Orifices. 3. Method of Designing a Steam Turbine. 4. Complete Designs for DeLaval Steam Turbines; Method of Making Vanes; Shrouding. 5. The Theory of Multiple Stage Turbines. Fully illustrated with detail drawings and tables.

MECHANICAL DRAWING, simply explained. Use of instruments, reading and setting out drawings, inking in and finishing, drawings for reproduction, lettering, with 44 illustrations.

ACETYLENE GAS. How to make and use it. A practical handbook on the uses of Acetylene Gas, suitable apparatus for its generation, hints and fitting up, etc. 34 illustrations.

LETTERING FOR DRAWINGS. A System of Easy Lettering, by J. H. Cromwell, with an appendix of eight new alphabets by G. Martin. Giving a variety of very attractive alphabets suitable for engineering and architectural drawings. **8th thousand. 50c.**

PROJECTION DRAWING. Twelve plates on, by Oswald Gueth, M.E., Inst. Mech. Drawing, Cooper Inst., N. Y. Arranged in three sections: *Projections*, plate 1, Prisms; 2, Pyramids; 3, Inclined Prisms; 4, Inclined Pyramids. *Sections*, plate 5, Prisms and Pyramids; 6, Cones; 7, Spheres; 8, Various Solids. *Intersections*, plate 9, Prisms; 10, Cylinders; 11, Spheres; 12, Prisms and Pyramids. **Size, 8½ x 11 in., sewn, 75c.**

ENGINEERING MATHEMATICS. Simply explained. A textbook for students, apprentices and engineers. By H. H. Harrison. **165 pages, 59 diagrams, cloth, 75c.**

ALGEBRA SELF-TAUGHT. By W. P. Higgs. 7th edition. The simplest and best book for beginners, mechanics, young engineers and electricians. Commencing from the very beginning, and advancing step by step, with many practical examples worked out. The signs given are fully explained. The language used is so simple that a student can readily master algebra by a little home study. This is the book to help the young man get into a better position. **Bound in cloth, 60c.**

EDUCATIONAL WOODWORK. By A. C. Horth. A complete manual for teachers and organizers of woodworking classes. Contents of Chapters: 1. First Year Course. 2. Second Year Course. 3. Third Year Course. 4. Fittings and Furniture. 5. Discipline. 6. Organization and Method. 7. The Instruction of the Physically and Mentally Deficient and Blind. 8. Object Lessons. Fully illustrated with reproductions from photographs, drawings, and facsimile black-board lessons. **158 pages, 12mo., cloth, $1.00 net.**

WOODWORK JOINTS. How to make and where to use them; including mortise and tenon joints, lap joints, dovetail joints, glue joints and scarfing joints. With a chapter on circular woodwork, revised and enlarged edition, 101 pages, 178 illustrations. **25c.**

THE BEGINNER'S GUIDE TO FRETWORK. Containing full instructions on the Use of Tools and Materials; and six full size Fretwork designs. With 39 pages and 26 illustrations. **25c.**

VENEERING, MARQUETRY AND INLAY. A practical instruction book in the art of Decorating Woodwork by these methods. By P. A. Wells. 79 pages, 37 illustrations. **25c.**

SOFT WOODS AND COLONIAL TIMBERS. The selection and Uses of Soft Woods and Colonial Timbers. The cultivation, cutting and seasoning. 57 pages, 15 illustrations. **25c.**

HARD WOODS, ENGLISH AND FOREIGN. A practical description of Hard and Fancy Woods used by the carpenter and cabinet maker. By P. A. Wells, 79 pages, 19 illustrations, **25c.**

THE LATEST AND MOST COMPLETE WORK FOR RAILROAD ENGINEERS.

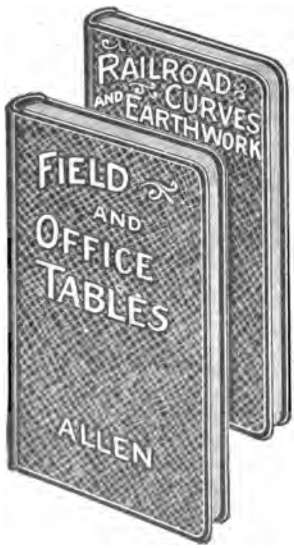
RAILROAD CURVES AND EARTHWORK

AND

FIELD AND OFFICE TABLES

(JUST OUT.)

In 2 Vols., limp leather, round corners, gilt edges, each $2.00,
Or two books in 1 Vol., $3.00.



BOOKS WILL BE MAILED TO ANY PART OF THE WORLD POSTPAID ON RECEIPT OF PRICE.

ALSO A LIST OF OTHER POCKETBOOKS SUITABLE FOR ENGINEERS.

Correspondence with book buyers solicited

☞The sample pages in this list are copyrighted.

AN ELEMENTARY TEXT-BOOK

ON

STEAM ENGINES AND BOILERS,

FOR THE

USE OF STUDENTS IN SCHOOLS AND COLLEGES.

BY

J. H. KINEALY,

Professor of Mechanical Engineering, Washington University.

Illustrated with Diagrams and Numerous Cuts, Showing American Types and Details of Engines and Boilers.

This book is written solely as an elementary text-book for the use of beginners and students in engineering, but more specially for the students in the various universities and colleges in this country.

No attempt has been made to tell everything about any one particular subject, but the author has endeavored to give the student an idea of elementary thermodynamics, of the action of the steam in the cylinder of the engine, of the motion of the steam valve, of the differences between the various types of engines and boilers, of the generation of heat by combustion, and the conversion of water into steam.

Care has been taken not to touch upon the design and proportion of the various parts of engines and boilers for strength; as, in the opinion of the writer, that should come after a general knowledge of the engine and boiler has been obtained.

In the derivation of some of the formulæ in thermodynamics, it has been necessary to use the calculus, but the use of all mathematics higher than algebra and geometry has been avoided as much as possible.

An earnest endeavor has been made to present the subject in a clear and concise manner, using as few words as possible and avoiding all padding.

CONTENTS OF CHAPTERS.

[illegible]